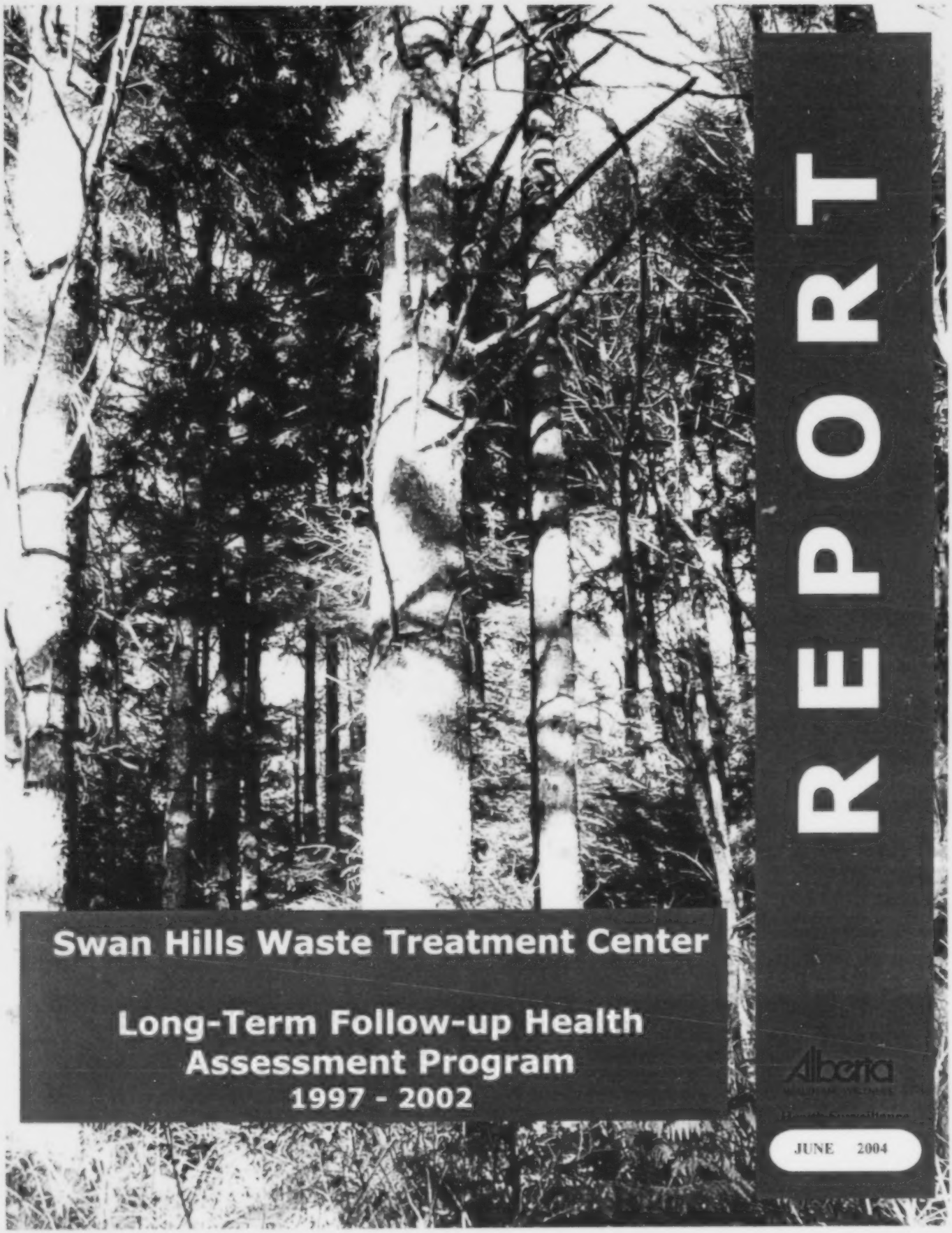

Swan Hills Waste Treatment Center

Long-Term Follow-up Health Assessment Program 1997 - 2002

REPORT

Alberta

JUNE 2004

Swan Hills Waste Treatment Center

Long-Term Follow-up Health Assessment Program

1997 - 2002

Health Surveillance
Alberta Health and Wellness

June 2004

For more information contact:
Health Surveillance
Alberta Health and Wellness
24th Floor, TELUS Plaza North Tower
P.O. Box 1360
10025 Jasper Avenue, STN Main
Edmonton, Alberta
T5J 2N3
Telephone: 1-780-427-1470
ISBN: 0-7785-2690-9 (Print)
ISBN: 0-7785-2691-7 (PDF)

105-04235/

EXECUTIVE SUMMARY

The Swan Hills Waste Treatment Centre (SHWTC) is a facility for the safe disposal of special wastes located approximately 12 kilometres north-east of the Town of Swan Hills. On October 16, 1996, a malfunction of a transformer furnace was discovered which had caused the flow of a portion of process gases containing polychlorinated biphenyls (PCBs), dioxins and furans (PCDD/Fs) into the ambient air. In 1997, Alberta Health and Wellness conducted a human health risk assessment study to estimate human exposure and evaluate the effectiveness of public health interventions. As the results of the study, food consumption advisories were issued for wild game and fish taken within a 30 km radius of the facility..

A long-term environmental monitoring and human exposure assessment program has been ongoing since 1998 to continue monitoring of concentrations of PCBs and PCDD/Fs in wild game and fish, review current food consumption advisories and protect public health for the local residents. As part of this long-term monitoring program, human blood monitoring, wildlife tissue monitoring, fish tissue monitoring, a background contaminants survey and exposure assessment have been conducted.

The results of the long-term studies indicate that:

1. Concentrations of PCBs and PCDD/Fs in blood in residents living the Swan Hills area are similar in the 1997 and 2001 surveys.
2. The levels of total PCB's and compounds of similar toxicity increased in the liver of deer in 2001 as compared to those in the 1997 and 1999 studies.
3. Overall levels of total PCB's and compounds of similar toxicity in the muscle of deer in 2001 and 1999 declined as compared to the 1997 levels.
4. Overall total levels of dioxins and furans in the liver of deer declined in 2001 as compared to the 1997 levels but increased as compared to 1999 levels.
5. The total dioxin and furan levels in the muscle of deer in 1999 and 2001 increased as compared to the 1997 levels.
6. The total levels of dioxins, furans and similar compounds increased in the liver and muscle of deer in 2001 as compared to those in the 1997 and 1999 studies.
7. Distribution patterns of total dioxins, furans, PCB's and compounds of similar toxicity in deer in the 1999 and 2001 studies were consistent with those observed in the 1997 study and the annual monitoring programs conducted by the company.
8. The inverse relationship between concentrations of dioxins and furans, and PCB's in deer tissues and distance to the facility suggests that the contamination is limited to the immediate vicinity of the facility.
9. The mean concentrations of total dioxins, furans, PCB's, and compounds of similar toxicity in the muscles and livers of brook trout from Chrystina Lake in 2000 were significantly lower compared to those taken in 1997.
10. Exposure ratios for PCB's, dioxins and furans were less than one (<1) for consuming muscle tissues of wild game and brook trout, suggesting that concentrations of these compounds are below published Health Canada total daily intake levels for consumption.
11. In the 2001 consumption study, the exposure ratios for PCB's, dioxins and furans in the

high intake group (two grams of liver per day) of wild game were four--fold higher than the Total Daily Intake value proposed by Health Canada for tetrachloro-dibenzodioxin.

12. The mean concentrations of total mercury in brook trout taken from Chrystina Lake were less than 200 µg/kg in 1999 and 2001.
13. Exposure ratios for mercury were greater than one for the high intake group of women of childbearing age and for children consuming brook trout, suggesting that concentrations of these compounds are above published Health Canada total daily intake levels for consumption.

The recommendations include that

1. The current food consumption advisories for dioxins and furans and PCBs should continue.
2. Women of childbearing age and children should not consume a large quantity of brook trout caught from Chrystina Lake due to the mercury levels in fish tissue.
3. A long-term human health and environmental monitoring program should continue, including wild game monitoring, fish monitoring and human blood monitoring.
4. Review of the food consumption advisories should be on-going .

ACKNOWLEDGEMENTS

Alberta Health & Wellness

Weiping Chen
Dr. Stephan Gabos
Dr. Donald Schopflocher
Alex MacKenzie

Centre for Toxicology

Dr. Siu Chan
Jasna Dmitrovic

Fisheries and Oceans Canada

Dr. Michael Ikonomou

Regional Health Authorities

Dr. Paul Schnee

University of Alberta

Dr. Ellie Prepas

Environment Canada

Dr. William Strachan

Assistance with wild game meat and fish collection by Alberta Environment and D.S. Prince Associates, and proof reading by Dr. Karina Bodo are gratefully acknowledged. Cooperation from blood donors from local communities is greatly appreciated.

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1. Introduction

The Swan Hills Waste Treatment Centre (SHWTC) is a facility for the safe disposal of special wastes located approximately 12 kilometers northeast of the town of Swan Hills. On October 16, 1996, a malfunction of a transformer furnace was discovered to have caused the release of a portion of process gases containing polychlorinated biphenyls (PCBs), polychlorinated dibenzo-ρ-dioxins and dibenzofurans (PCDD/Fs) into the ambient air. In 1997, Alberta Health and Wellness conducted a human health risk assessment study to estimate human exposure and to evaluate the effectiveness of public health interventions. As a result of the study, food consumption advisories for wild game and fish taken within a 30 km radius of the facility were issued.

A long-term environmental monitoring and human exposure assessment program has been ongoing since 1998 to monitor concentrations of PCBs and PCDD/Fs in wild game and fish, to review current food consumption advisories and to protect the health of local residents. As part of this long-term monitoring program, human blood monitoring, wildlife tissue monitoring, fish tissue monitoring, background contaminants survey and exposure assessment were conducted.

In this report, information from the following studies is presented:

(1). The results of a blood survey of the residents of the Swan Hills area in 2001;
(2). The results of analyses of tissues of deer taken within a 30 km radius of the facility and the reference areas in 1999 and 2001 for concentrations of PCBs and PCDD/Fs;
(3). The results analyses of tissues of fish caught from Chrystina Lake in 2000 for concentrations of PCBs and PCDD/Fs of concentrations of PCBs and PCDD/Fs in the tissues;
(4). The estimation of human exposure to PCBs and PCDD/Fs through consumption of wild game and fish from the Swan Hills area;
(5). The results of analyses of the tissues of fish caught from Chrystina Lake in 1999 and 2001 for concentrations of mercury;
(6). The estimation of human exposure to mercury through consumption of fish from Chrystina Lake; and
(7). The results of a background contaminants survey conducted between 1999 and 2001.

2. Human Tissue Monitoring: Blood

2.1 Materials and Methods

2.1.1 Recruitment Procedures

The target population for the blood monitoring study consisted of individuals over the age of 18 years who resided in communities in the Swan Hills area and who had participated in the 1997 Swan Hills Health Assessment Survey. The study area included the town of Swan Hills and all communities within a 100 km radius, including Fox Creek, Little Smoky, Sunset House, High Prairie, Enilda, Joussard, Driftpile, Faust, Kinuso, Canyon Creek, Widewater, Slave Lake, Fort Assiniboine and Swan Hills (Figure 2-1). The sampling frame was the 1997 Swan Hills Health Assessment survey files. Telephone numbers were present in those files.

Figure 2-1 Communities in the Swan Hills and its Surrounding Areas

An initial telephone survey was conducted to identify potential participants. A total of 146 residents were contacted in May, 2001. Of these, 81 gave verbal consent to participating in the food consumption survey and agreed to provide blood samples. In June, a cover letter, consent form and a list of contact names and locations for regional health authorities (RHAs) blood sampling sites were mailed out to each eligible participant.

2.1.2 Sample Collection

A total of 38 participants contacted managers in the designated health care centers during July and August of 2001. After the consent forms had been explained, participants signed these forms under the manager's witness. Blood samples were then collected. Sample collection took place at the following hospitals: Swan Hills General Hospital, Slave Lake General Hospital, High Prairie Complex, and Barrhead Hospital.

Serum specimens were collected according to a standard protocol. About 50 ml of venous blood was collected from each participant via venipuncture into five 10 ml-Red Top Vacutainers. The specimens were allowed to clot for 30 minutes and then centrifuged for 15 to 20 minutes. Sera were transferred with a glass pipette to an acetone-washed glass vial with a Teflon cap liner. All serum specimens were packed with an ice pack and shipped to the Centre for Toxicology Laboratory via next-day courier in early September. The completed consent forms were mailed to Health Surveillance, Alberta Health and Wellness. On completion of the PCB analysis, the remaining serum samples were shipped to the Regional Dioxin Laboratory, Institute of Ocean Sciences, Fisheries and Oceans Canada in Sidney, British Columbia.

2.1.3 PCB Analysis

The Centre for Toxicology in Calgary performed the chemical analyses. The serum sample was homogenized by vortexing for five minutes. Two ml of the sample were mixed with 2 mL of glacial acetic acid and 2 mL of methanol. Five ng each of CB 114, CB 189 and CB 202 were also added as internal standards. This mixture was then sonicated for 30 min. Extraction was performed with a Bond Elut C18 (Varian, Harbor City, CA) column and a Sep-Pak Plus NH2 (Waters, Milford, MA) cartridge. Further clean up of the extract was performed with a Bond Elute SPE PCB (Varian) cartridge. The PCBs were collected in 9 mL of n-hexane. Moisture was removed from the organic solvent using anhydrous sodium sulfate. Five hundred µL of isooctane were added to the n-hexane, and the volume was reduced to about 100 µl at 40°C under a stream of nitrogen. Two µl were injected into a Hewlett-Packard 5973 GC/MS using the technique of negative chemical ionization. The mass spectrometer was operated in the selected ion-monitoring mode and three diagnostic ions were monitored for each PCB congener.

Two groups of PCBs were analyzed. The PCBs in Group I were 70, 74, 87, 99 and 101. Those in Group II were 77, 105, 118, 126, 128, 138, 151, 153, 156, 169, 170, 180, 183, 187, 191, 194, 205, 206, 208 and 209. Quantitation of PCBs in a serum sample was carried out by comparison with their respective calibration curves. For Group I PCBs, the calibrations ranged from 0.1 to 2.0 ng/ml, while those of Group II ranged from 0.01 to 0.2 ng/ml.

Lipid content of the serum sample was determined by the gravimetric method. One mL of the homogenized sample was mixed with 200 µL of ammonia and 1 mL of ethanol. The mixture was thoroughly mixed in a mechanical shaker. The lipids were extracted with 5 mL of diethyl ether and 5 mL of petroleum ether. The organic solvents were then transferred to a pre-weighed culture tube and dried under a gentle stream of nitrogen at 40°C. The test tube was weighed again and the amount of lipids in the sample was determined by difference.

2.1.4 PCDD/F Analysis

PCDDs/Fs determinations for 38 extract samples were performed by the Fisheries and Oceans Regional Dioxin Laboratory at the Institute of Ocean Sciences in Sidney, British Columbia. The methodologies used to process the samples, the criteria used for identification and quantification and the quality assurance/quality control protocols are described in detail elsewhere (Ikonomou *et al.* 2001). From each sample four aliquots were collected from the carbon-fibre fractionation, the last part of the sample clean-up process. Fraction-IV contained the PCDDs and PCDFs. Analysis of all fractions was conducted by high-resolution gas chromatograph/high-resolution mass spectrometry (GC/HRMS). For all analyses, the MS was operated at 10 000 resolution under positive EI conditions and data were acquired in the Single Ion Monitoring Mode (SIM). The concentrations of identified compounds and their minimum detection limits (MDLs) were calculated by the internal standard method using mean relative response factors determined from calibration standard runs, made before and after each batch of samples was run. Detection limits ranged from 0.29 to 0.61 pg/g for PCDDs/Fs.

2.2 Results and Discussions

The central tendencies of PCB concentrations (summed over all 25 congeners) in blood in 2001 and 1997 surveys were summarized in Table 2-1 and Table 2-2. In most Canadian studies, the average PCB levels in blood are about 1 – 2 µg/L, whole weight (Lebel *et al.* 1998). The means of PCB levels were slightly lower in both surveys (2001 - 0.67 µg/L, whole weight and 1997 - 0.73 µg/L, whole weight).

Thirteen of 25 congeners were detected in blood, including CB-74, 105, 118, 138, 153, 156, 170, 180, 183, 187, 194, 206 and 208. The predominating compounds were CB-153, CB-180 and CB-138. The means of CB-153, CB-180 and CB-138 were 0.20, 0.13, and 0.10 µg/L, whole weight, respectively. The means of these three congeners are similar to the means from other Canadian studies (Mes 1997). The means of CB-153, CB-180 and CB-138 in these studies were 0.12, 0.12, and 0.11 µg/L, whole weight, respectively.

Figure 2-2 shows that mean PCB concentrations increased with age. The PCB concentrations were increased with age.

Table 2-1 PCB Concentrations in Blood (μg/L, whole weight) in 2001 Survey

IUPAC No.	Mean	Min	Max	Median	Proportion
70	nd	nd	nd	nd	nd
74	0.01	nd	0.12	nd	1.88
77	nd	nd	nd	nd	nd
87	nd	nd	nd	nd	nd
99	nd	nd	nd	nd	nd
101	nd	nd	nd	nd	nd
105	nd	nd	0.02	nd	0.47
118	0.04	0.02	0.17	0.03	6.36
126	nd	nd	nd	nd	nd
128	nd	nd	0.01	nd	0.47
138	0.10	0.01	0.31	0.09	15.47
151	nd	nd	nd	nd	nd
153	0.20	0.04	0.91	0.18	29.76
156	0.03	nd	0.18	0.03	4.63
169	nd	nd	nd	nd	nd
170	0.05	0.01	0.21	0.05	7.73
180	0.13	0.03	0.53	0.11	19.67
183	0.01	nd	0.05	0.01	1.85
187	0.04	0.00	0.18	0.04	6.67
191	nd	nd	nd	nd	nd
194	0.02	nd	0.10	0.02	3.26
205	nd	nd	nd	nd	nd
206	0.01	nd	0.22	nd	1.69
208	nd	nd	0.02	nd	0.08
209	nd	nd	nd	nd	nd
Total	**0.67**	**0.14**	**2.85**	**0.57**	**100**

nd = non-detect (or not detected)

Table 2-2 PCB Concentrations in Blood (μg/L, whole weight) in 1997 Survey

IUPAC No.	Mean	Min	Max	Median	Proportion
70	nd	nd	0.13	nd	0.31
74	0.01	nd	0.61	nd	1.46
77	nd	nd	nd	nd	nd
87	0.01	nd	0.36	nd	0.86
99	nd	nd	0.21	nd	0.50
101	0.01	nd	0.39	nd	0.93
105	0.01	nd	0.13	nd	1.17
118	0.03	nd	0.28	0.02	4.42
126	nd	nd	0.01	nd	0.05
128	0.03	nd	0.10	0.02	3.42
138	0.24	0.03	1.03	0.17	32.66
151	0.01	nd	0.18	nd	0.93
153	0.16	0.03	0.60	0.13	21.28
156	0.02	nd	0.08	0.02	2.77
169	0.01	nd	0.14	nd	0.79
170	0.04	nd	0.16	0.03	5.43
177	0.01	nd	0.05	0.01	1.12
180	0.10	nd	0.44	0.08	13.20
183	0.01	nd	0.06	0.01	1.72
187	0.03	nd	0.16	0.03	4.28
191	nd	nd	0.01	nd	0.24
194	0.01	nd	0.10	0.01	1.98
205	nd	nd	nd	nd	nd
206	nd	nd	0.02	nd	0.48
208	nd	nd	nd	nd	nd
209	nd	nd	nd	nd	nd
Total	**0.73**	**0.07**	**4.22**	**0.59**	**100**

nd = non-detect (or not detected)

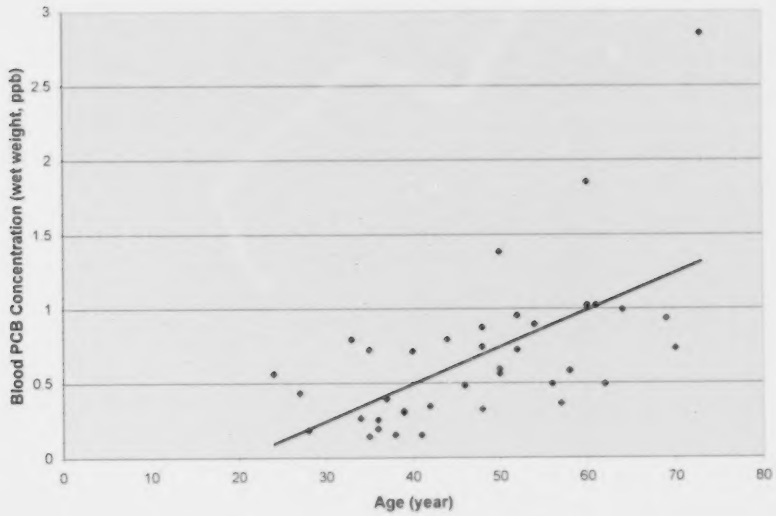

Figure 2-2 PCB Concentrations vs. Age

The means of PCDD/Fs concentrations in blood in the 2001 survey are summarized in Table 2-3. The means of PCDD/Fs concentrations in 2001 (29 pg/ml, whole weight and 4922 pg/g, lipid basis) were not significantly different from those in 1997 survey (22 pg/ml, whole weight and 5112 pg/g, lipid basis). The prevalent congeners were OCDD (67%) and 1,2,3,6,7,8-HxCDD (17%).

The means of PCDD/Fs TEQ values in blood in 2001 survey were summarized in Table 2-4. The means of PCDD/Fs TEQ in 2001 (152 pg/g, lipid basis) were significantly higher than those in the 1997 survey (18 pg/g, lipid basis). The higher TEQ values were attributed to1,2,3,6,7,8-HxCDD (49%) and 1,2,3,7,8-PeCDD (24%).

2.3 Summary

Concentrations of PCBs and PCDD/Fs in blood are similar in residents living the Swan Hills area in 1997 and 2001 surveys. TEQ values of PCDD/Fs in the 2001 survey are higher than those in the 1997 survey. The higher TEQ values can be attributed to higher levels of 1,2,3,6,7,8-HxCDD and 1,2,3,7,8-PeCDD.

Table 2-3 Means of Concentrations of PCDD/Fs in Blood in 2001 Survey

Parameter	Whole Weight (pg/ml)		Lipid Weight (pg/g)	
	Conc.	%	Conc.	%
Lipid content				0.61
2,3,7,8-TCDD	0.02	0.07	3.59	0.07
1,2,3,7,8-PeCDD	0.23	0.82	35.66	0.72
1,2,3,4,7,8-HxCDD	0.13	0.46	21.11	0.43
1,2,3,6,7,8-HxCDD	4.51	15.74	743.64	15.11
1,2,3,7,8,9-HxCDD	0.28	0.99	49.19	1.00
1,2,3,4,6,7,8-HpCDD	2.28	7.95	390.25	7.93
OCDD	19.42	67.75	3371	68.49
2,3,7,8-TCDF	<0.39	-	-	-
1,2,3,7,8-PeCDF	<0.24	-	-	-
2,3,4,7,8-PxCDF	0.22	0.78	33.93	0.69
1,2,3,4,7,8-HxCDF	0.20	0.70	32.93	0.67
1,2,3,6,7,8-HxCDF	0.28	0.99	45.73	0.93
1,2,3,7,8,9-HxCDF	0.03	0.10	4.75	0.10
2,3,4,6,7,8-HxCDF	<0.23	-	-	-
1,2,3,4,6,7,8-HpCDF	0.77	2.69	142.04	2.89
1,2,3,4,7,8,9-HxCDF	<0.32	-	-	-
OCDF	0.28	0.97	48.08	0.98
∑PCDDs/Fs	**29**	100	**4922**	100

Table 2-4 Means of PCDD/F TEQ Values in Blood in 2001 Survey

Parameter	Whole Weight (pg/ml)		Lipid Weight (pg/g)	
	Conc.	%	Conc.	%
Lipid content				0.61
2,3,7,8-TCDD	0.02	2.10	3.59	2.37
1,2,3,7,8-PeCDD	0.23	24.87	35.66	23.52
1,2,3,4,7,8-HxCDD	0.01	1.39	2.11	1.39
1,2,3,6,7,8-HxCDD	0.45	47.92	74.36	49.05
1,2,3,7,8,9-HxCDD	0.03	3.00	4.92	3.24
1,2,3,4,6,7,8-HpCDD	0.02	2.42	3.90	2.57
OCDD	0.00	0.21	0.34	0.22
2,3,7,8-TCDF	-	-	-	-
1,2,3,7,8-PeCDF	-	-	-	-
2,3,4,7,8-PxCDF	0.11	11.82	16.96	11.19
1,2,3,4,7,8-HxCDF	0.02	2.13	3.29	2.17
1,2,3,6,7,8-HxCDF	0.03	3.02	4.57	3.02
1,2,3,7,8,9-HxCDF	0.00	0.29	0.48	0.31
2,3,4,6,7,8-HxCDF	-	-	-	-
1,2,3,4,6,7,8-HpCDF	0.01	0.82	1.42	0.94
1,2,3,4,7,8,9-HxCDF	-	-	-	-
OCDF	-	-	-	-
∑PCDDs/Fs	**0.94**	100	**152**	100

Toxic equivalency factors (TEFs): WHO 1997 values (van Leeuwen 1997)

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3. Wildlife Tissue Monitoring: Deer

3.1 Materials and Methods

3.1.1 Field Collection

1997

Both fresh and frozen tissues samples were collected. Fresh deer samples were taken directly from the area designated for the study. Three whitetail deer were collected at distances of 10 km, 20 km, 30 km to the east of the facility. Eleven road-kill adult deer carcasses were collected from other locations in Alberta as a control group. Frozen deer and moose samples were taken from animals preserved in home freezers and donated by local licensed hunters and First Nations people. Approximately 40 people donated sixty frozen deer and moose meat samples collected between October 1996 and February 1997 from within a 30 km kilometer radius of the facility. All specimens consisting of muscle, liver and kidney were kept frozen at -20° C prior to laboratory analysis.

1998-1999

Field collection was carried out in December 1998 and January 1999. Nine whitetail deer and mule deer were collected at distances of 1 - 25 km to the east and west of the Special Waste Treatment Center. Ten deer were collected at a distance of 100 km to the west of the facility as a control group. Representative muscle and liver samples were taken from each deer. All samples were kept frozen at - 20° C prior to laboratory analysis.

2000 – 2001

Field collection was carried out in December 2000 and January 2001. Six whitetail deer and mule deer were collected at distances of 1 - 30 km to the east and west of the Special Waste Treatment Center. Representative muscle, liver and fat samples were taken from each deer. All samples were kept frozen at - 20° C prior to laboratory analysis.

3.1.2 PCBs and PCDD/Fs Analysis

1997

PCDDs/Fs and PCBs determinations for all samples were performed by the MAXXAM Laboratory, Mississauga, Ontario. Analytical methods and QA/QC assurance were described in Environment Canada EPS 1/RM/23 (1992), Environment Canada AMD 96-05 (1996) and USEPA Method 1613 (1994). Each sample was homogenized and sub-sampled for analysis. Prior to the initial extraction, samples were fortified with fifteen $^{13}C_{12}$-labeled PCDD/Fs with the exception of OCDF and eight $^{13}C_{12}$-labeled PCBs. Samples were digested overnight in concentrated hydrochloric acid and then extracted with 50/50 dichloromethane/hexane for one

hour. This extraction was repeated several times. Lipid content was determined gravimetrically from the remaining extract. The extracts were subjected to an acid/base silica cleanup, reconcentrated and split into two equal portions by weight. One portion, for PCDD/F analysis, was cleaned up on alumina following the standard operating procedure for PCDD/Fs. The PCB portion was cleaned up on a modified alumina column. Extracts were analyzed separately for PCBs and PCDD/Fs on an Autospec Ultima High Resolution Mass Spectrometer, interfaced with a Hewlett Packard Gas Chromatograph. PCBs were separated at EI 8,000 mode and PCDD/Fs at EI 10,000 mode. Fused silica capillary columns (60 meter, 0.25 mm ID, 0.25 μm film thickness) were used for determining PCDD/Fs and PCB congeners, respectively. Injector temperature was 265° C. The total time of the GC run was 50 min. Congeners were detected in the selected ion monitoring (SIM) mode.

1999 and 2001

PCDD/Fs and PCBs determinations for all samples were performed by the Fisheries and Oceans Regional Dioxin Laboratory at the Institute of Ocean Sciences in Sidney, British Columbia. The methodologies used to process the samples, the criteria used for identification and quantification and the quality assurance quality control protocols followed are described in detail elsewhere (Ikonomou *et al.* 2001). From each sample, four aliquots were collected from the carbon-fibre fractionation, the last part of the sample clean-up process. Fraction-I contained the di-ortho PCBs, fraction-II the mono-ortho PCBs, fraction-III the non-ortho PCBs and fraction-IV the PCDDs and PCDFs. In fractions I to III all the possible 209 PCB congeners were measured with minimum isomeric interference. Analyses of all fractions were conducted by high-resolution gas chromatograph/high-resolution mass spectrometry (HRGC/HRMS). For all analyses the MS was operated at 10000 resolution under positive EI conditions and data were acquired in the Single Ion Monitoring Mode (SIM). The concentrations of identified compounds and their minimum detection limits (MDLs) were calculated by the internal standard method using mean relative response factors determined from calibration standard runs, made before and after each batch of samples was run. Detection limits range from 0.01 to 0.12 pg/g for PCDD/Fs, 0.04 to 0.08 pg/g for non-ortho PCBs, 0.1 pg/g for mono-ortho PCBs and 0.1 to 0.2 pg/g for di-ortho PCBs.

3.2 Results and Discussions

3.2.1 PCBs and PCDD/Fs: 1997

Means for $\sum PCB_{homologs}$ and $\sum PCCD/F_{homologs}$, whole weight, were significantly elevated for all liver ($p<0.05$) and fat samples ($p<0.05$, with the exception of PCDD/Fs) in the study area relative to the Alberta control areas. ∑dioxin-like TEQ levels were significantly elevated in all types of samples ($p<0.05$) in the study area. ∑PCCD/F TEQ levels increased with a decrease of distance from the facility of 10, 20 and 30 km ($r= -0.849$, $p<0.005$). No apparent correlation was observed between contaminant levels and age and sex of deer. The results of $\sum PCB_{congener}$ and $\sum PCDD/F_{congener}$ levels in fresh samples are presented in Table 3-1.

Table 3-1 Summary of PCB and PCDD/F Levels in Fresh Deer Samples

Parameter	Study Area		Alberta Control	
	Liver	Muscle	Liver	Muscle
Sample size	3	3	11	11
Detects of PCBs	3	1	7	5
Detects of PCDD/Fs	3	2	10	4
Lipid content (%)	3.20	1.87	3.42	1.64
Mean of $\sum PCB_{congener}$* (μg/kg, lipid basis)	1178	509	194	158
(range)	(103-2799)	(nd-1527)	(nd-1177)	(nd-821)
% of $\sum PCB_{congener}/\sum PCB_{homologs}$	43	43	39	26
% of measured congeners from each homologue group** / $\sum PCB_{congener}$				
di-PCB	10.43	26.20	17.11	12.60
tri-PCB	2.28	2.08	15.65	21.56
tetra-PCB	3.32	4.56	13.38	15.51
penta-PCB	8.60	9.14	12.17	11.50
hexa-PCB	36.84	30.25	27.33	27.67
hepta-PCB	36.17	24.64	9.05	10.52
octa-PCB	2.38	2.88	0.45	nd
deca-PCB	0.19	0.26	nd	nd
TEQ (ng/kg, lipid basis)				
$\sum$ *non-ortho* PCB***	1259	986	1	3
$\sum$ *mono-ortho* PCB***	20	9	35	2
$\sum$ *di-ortho* PCB ***	12	4	0.06	0.09
$\sum$ PCDD/F	4698	32	100	9
$\sum$ Dioxin-like compounds**** (range)	5989	1031	136	13
	(74-9198)	(14-3038)	(15-819)	(0.98-92)
% of $\sum$PCB/$\sum$Dioxin-like compounds	22	97	26	35
% of $\sum$PCDD-F/$\sum$Dioxin-like compounds	78	3	74	65
% of $\sum$*non-ortho*-PCB/$\sum$Dioxin-like compounds	21	96	0.77	21

* Sum of 44 individual congener levels ** congener #8 in di-CB, #18, #28, #33, #37 in tri-CB, #44, #49, #52, #70, #74, #77, #81 in tetra-CB, #87, #99, #101, #114, #118, #119, #123, #126 in penta-CB, #128, #137, #138, #151, #153, #156, #157, #158, #167, #168, #169 in hexa-CB, #170, #177, #180, #183, #187, #189, #191 in octa-CB, NA in nona-, and #209 in deca-CB. *** *non-ortho-* = CB (No.) 77, 126, 169, *mono-ortho-* = CB (No.) 105, 114, 118, 123, 156, 157, 167, 189, *di-ortho-* = CB (nos.) 170, 180 **** $\sum$CB-TEQ plus $\sum$PCDD/F-TEQ

A wide range of individual PCB congeners were detected. Hexa- (36%) and hepta-chlorobiphenyls (25%-30%) were the major PCB homologue groups in the samples from the study area while tri-, tetra-, octa- and deca- chlorobiphenyls were minor constituents. CB 8, 138, 153, and 180 constituted 55% to 64% of $\sum PCB_{congener}$ in liver and muscle samples from the study area. With the exception of muscle samples from the study area, the majority of $\sum$dioxin-like TEQ was due to PCDD/Fs, ranging from 65% to 78%. 2,3,4,7,8-penta CDF was prevalent in the liver samples from the study area, accounting for 30% of $\sum$dioxin-like TEQ. In contrast, 1,2,3,6,7,8-hexa CDD was the major congener in the liver (37%) and muscle (44%) from the control areas. 2,3,7,8-TCDD was not detected in the samples from the study area (at a detection limit of 0.5 ng/kg whole weight). $\sum$dioxin-like TEQ in muscle from the study area was largely due to PCBs. *Non-ortho* CB 126 was prevalent, accounting for 97% of $\sum$dioxin-like TEQ. CB126 was not detected in the control samples. The findings are consistent with the results in the company's monitoring programs in which CB 126, 138, 153 and 180 were found as major

contributors in vegetation, soil, spruce needle and snow pack near the facility.

PCBs and PCDD/Fs were detected in 21 out of 50 frozen muscle samples and in 8 out of 10 liver and kidney samples. Means for $\sum PCB_{homologs}$ and $\sum PCCD/F_{homologs}$ were significantly elevated for all muscle samples from within the 20 km radius relative to outside the 20 km radius of the facility. Hexa-chlorobiphenyls was the dominating PCB homologue group (76%) in all muscle samples. The majority of ∑dioxin-like TEQ was due to PCBs, with CB 126 accounting for 86% of ∑dioxin-like TEQ.

Significantly higher levels of PCBs and PCDD/Fs in deer from the study area and similar PCB congener patterns observed in various media near the facility indicate that contamination has occurred in the ecosystems near the facility. Specifically, an air-plant-herbivore pathway of contamination is implicated. Many studies have shown that an increased atmospheric deposition of PCBs contributes to an increased PCB burden in plants and herbivores (Eisler and Belisle 1995, INAC 1997, Larsson *et al.* 1990). Lichens, moss and browse (as the primary food items of herbivores for the winter) are abundant in the vicinity of the facility and used to monitor airborne pollutants. The mobility of deer and moose is restricted to a relatively small area in harsh winters. Deer and moose in the study area are likely to consume plants nearby. The inverse relationship between measured contaminant levels in deer and distance from the facility suggested the occurrence of the air-plant-herbivore pathway.

Accumulation of PCB congeners varies within different types of environmental samples and locations. The higher-chlorinated congeners have been more frequently observed in marine food chains and predators while the lower-chlorinated congeners are abundant in herbivores because lower chlorinated congeners are more likely to persist in vegetation (Larsson *et al.* 1990, Muir *et al.* 1988). Some studies reported an increased level of lower-chlorinated congeners in various animals in recent years (Georgii *et al.* 1994). The similar distribution of lower and higher chlorinated congeners in Alberta control samples implies that the potential exposure for deer in most of Alberta come from remote air transport and diverse sources.

Non-ortho PCBs (77, 126 and 169) are widely distributed in the environment but at very low levels. Low levels of *non-ortho* PCBs were found in deer from Alberta controls. But a very high level for CB126 was observed in deer from the study area. *Non-ortho* PCBs were also detected in the samples of tealeaves, live moss, soil and voles near the facility in the company's monitoring program (Brown *et al.* 1995; Kimbrough 1995). Combustion processes could be the source of the increased environmental levels of the coplanar congeners characterized by 3,3',4,4' substitution such as CB 169, 126, 77, 105, 156, 157, 170 and 189. CB 77 has been found to be more biodegradable than CB126 and CB169 (Kannan *et al.* 1989, Tanabe *et al.* 1987). The increased level of CB126 in environmental media and the highly biodegradable nature of CB 77 may have caused a high level of CB126 in deer collected near the facility.

3.2.2 PCBs: 1999 - 2001

The mean values of ΣPCBs and their homologues are summarized in Table 3-2, 3-3 and 3-4. In the 1999 study, 47 of 209 PCB congeners were not detected in the muscle samples, and 38 congeners were not detected in the liver. In the 2001 study, 49 of 209 PCB congeners were not

detected in the muscle samples, 45 congeners were not detected in the liver and 35 congeners were not detected in the fat. The mean level of PCB homologues in the 1999 study was 21 ng/g, lipid basis in the muscle and 47 ng/g in the liver in the study area, and 5.3 ng/g, lipid basis in the muscle and 5 ng/g in the liver in the reference areas. *Di-ortho* PCBs constituted 79% to 84% of ΣPCBs as compared to 55% to 58% in the control areas. The mean level of PCB homologues in the 2001 study was 291 ng/g, lipid basis in the muscle, 317 ng/g in the liver, and 506 ng/g in the fat. *Di-ortho* PCBs constituted 82% to 92% of ΣPCBs.

Table 3-2 Means of PCBs Homologues in Deer Muscle (ng/g, lipid basis)

Group	2001 Study Area (N=6)	1999 Study Area (N=9)	1999 Control Area (N=10)	Group	2001 Study Area (N=6)	1999 Study Area (N=9)	1999 Control Area (N=10)
*Non-ortho**				*Di-ortho****			
di-CBs	0.67	0.40	0.23	*di-CBs*	0.23	0.04	0.06
tri-CBs	1.17	0.24	0.08	*tri-CBs*	1.58	0.34	0.31
tetra-CBs	0.51	0.09	0.06	*tetra-CBs*	5.72	0.75	0.49
penta-CBs	0.13	0.07	0.01	*penta-CBs*	22.03	1.25	0.53
hexa-CBs	0.04	0.004	0.002	*hexa-CBs*	115.67	7.58	1.00
Total *non-ortho*	**2.52**	**0.80**	**0.38**	*hepta-CBs*	79.49	4.74	0.46
				octa-CBs	28.19	1.83	0.16
				nona-CBs	2.34	0.24	0.04
*Mono-ortho***							
di-CBs	0.00	0.32	0.72	*deca-CBs*	0.37	0.08	0.07
tri-CBs	3.46	0.92	0.68	**Total *di-ortho***	**256**	**16.86**	**3.11**
tetra-CBs	7.74	0.39	0.20				
penta-CBs	13.75	1.32	0.21	**Total CBs**	**291**	**21**	**5.3**
hexa-CBs	7.05	0.51	0.06	% of *non-ortho*	1.0	4.0	7.0
hepta-CBs	0.60	0.06	0.002	% of *mono-ortho*	11	17	35
Total *mono-ortho*	**32.6**	**3.52**	**1.87**	% of *di-ortho*	88	79	58

* Non-ortho CBs: di- (no.11-14), tri- (no. 35-39), tetra- (no. 77-81), penta- (no. 126, 127) and hexa- (no. 169). ** *Mono-ortho* CBs: di- (no.5-9), tri- (no. 20-23, 25-26, 28-29, 31, 33-34), tetra- (no. 55-58, 60-61, 63, 66-67, 68, 70, 72, 74, 76), penta- (no. 105, 107, 108, 111,114, 118, 120, 122-124), hexa- (no. 156, 157, 159, 162, 167) and hepta- (no.189). *** *Di-ortho* CBs: di- (no.4, 10), tri- (no. 16-19, 24, 27, 30, 32), tetra- (no. 40-54, 59, 62, 64, 69, 71, 73, 75), penta- (no. 82-104, 109-110, 112-113, 115-117, 119, 121, 125), hexa- (no. 128-155, 158, 160, 161, 163-166, 168), hepta- (no. 170-188, 190-193), octa- (no. 194-205), nona- (no.206-208) and deca- (no. 209).

Table 3-3 Means of PCBs Homologues in Deer Liver (ng/g, lipid basis)

Group	2001 Study Area (N=6)	1999 Study Area (N=9)	1999 Control Area (N=10)	Group	2001 Study Area (N=6)	1999 Study Area (N=9)	1999 Control Area (N=10)
Non-ortho				*Di-ortho*			
di-CBs	0.20	0.84	0.53	*di-CBs*	0.09	0.18	0.04
tri-CBs	0.27	0.28	0.10	*tri-PCBs*	0.67	1.01	0.21
tetra-CBs	0.28	0.18	0.04	*tetra-CBs*	1.34	2.19	0.41
penta-PCBs	16.60	0.96	0.02	*penta-CBs*	6.96	3.26	0.37
hexa-CBs	0.72	0.03	0.002	*hexa-CBs*	138.92	8.43	0.40
Total *Non-ortho*	**18.08**	**2.28**	**0.70**	*hepta-PCBs*	79.22	12.07	0.75
				octa-CBs	29.30	11.69	0.52
				nona-CBs	1.55	0.41	0.03
Mono-ortho							
di-CBs	0.18	0.35	0.34	*deca-CBs*	0.21	0.18	0.04
tri-CBs	2.25	1.16	0.89	**Total *di-ortho***	**258.2**	**39.42**	**2.77**
tetra-CBs	3.63	0.92	0.15				
penta-CBs	17.78	1.90	0.12	**Total CBs**	**317**	**47**	**5**
hexa-CBs	15.63	0.93	0.04	% of *non-ortho*	5.0	5.0	14
hepta-CBs	0.98	0.09	0.002	% of *mono-ortho*	13	11	31
Total *mono-ortho*	**40.43**	**5.35**	**1.54**	% of *di-ortho*	82	84	55

Table 3-4 Means of PCBs Homologues in Deer Fat in Study Area 2001 (ng/g, lipid basis)

Non-ortho		*Mono-ortho*		*Di-ortho*			
						nona-CBs	*3.58*
di-CBs	0.04	*di-CBs*	0.19	*di-CBs*	0.01	*deca-CBs*	0.27
tri-CBs	0.02	*tri-PCBs*	0.54	*tri-CBs*	0.08	**Total** *Di-ortho*	**466.7**
tetra-CBs	0.05	*tetra-CBs*	1.89	*tetra-CBs*	0.33		
penta-CBs	0.24	*penta-CBs*	22.53	*penta-CBs*	19.95	**Total CBs**	**506**
hexa-CBs	0.06	*hexa-CBs*	12.54	*hexa-CBs*	244.0	% of *non-ortho*	0.08
Total	**0.41**	*hepta-CBs*	0.85	*hepta-CBs*	157.1	% of *mono-ortho*	7.62
Non-ortho		**Total** *Mono-ortho*	**38.5**	*octa-CBs*	41.37	% of *di-ortho*	92.3

The concentration of ΣPCBs was significantly higher in the muscle and liver in 2001 than those in 1999. Particularly, the levels of penta-PCBs and hexa-PCBs in the mono-ortho group and hexa-PCBs and hepta-PCBs in the di-ortho group were largely increased. CB 153, CB 138 and CB 180 were the major contributing congeners to these increased levels (Figure 3-1 which shows the profiles on a log scale, and Figure 3-2 which shows a biplot, a two dimensional projection of the profiles for the congener profiles and simultaneously the separate sample sources). In the 1999 study, the abundant congeners in ΣCBs were CB-138 (9%), CB-153 (19%), CB-170 (6%) and CB-180 (9%) for samples from the study area. In the 2001 study, CB-153 accounted for 22% to 28% of ΣPCBs in all types of samples, 11% to 15% for CB-138 and 13% to 17% for CB180.

For samples from the 1999 reference area, CB-8, CB-28, CB-138, CB-153 and CB-180 accounted for 11%, 6%, 4%, 6% and 2% of ∑PCBs, respectively. The major contributors in deer from the reference site were the lower-chlorinated congeners. Lower chlorinated congeners are likely to persist in vegetation. Thus, they are more frequently detected in herbivores. High proportions of some higher chlorinated congeners observed in deer from the study area suggest different exposure sources for deer in this area.

Non-ortho PCBs constituted a very small proportion of ∑PCBs. Major contributors in the non-ortho PCBs group were CB-11, CB15 and CB-37 for all samples from the study and reference areas. CB-126 concentrations were significantly higher in the liver from the study area (838 pg/g, lipid basis, in 1999, and 16595 pg/g, lipid basis, in 2001) than those in the reference areas (9.87 pg/g, lipid basis). High proportions of CB-126 were often observed in various environmental samples collected near the facility (Operator, 1997, 1998, 1999, 2000, and 2001).

The highest ΣPCBs concentrations were observed in the tissues of one deer collected at a distance of 0.5 km from the facility in 2001 and one deer collected at a distance of 1.0 km from the facility in 1999 (Figure 3-3, 3-4, 3-5 and 3-6). Similar to the 1997 results (AHW, 1997), the PCBs concentrations in all the samples decreased with distance from the facility. The mobility of white-tail and mule deer is restricted to a radius of 4 to 5 km in winter. This finding suggests that contamination has occurred in the ecosystem in vicinity of the facility and that PCBs have accumulated in deer.

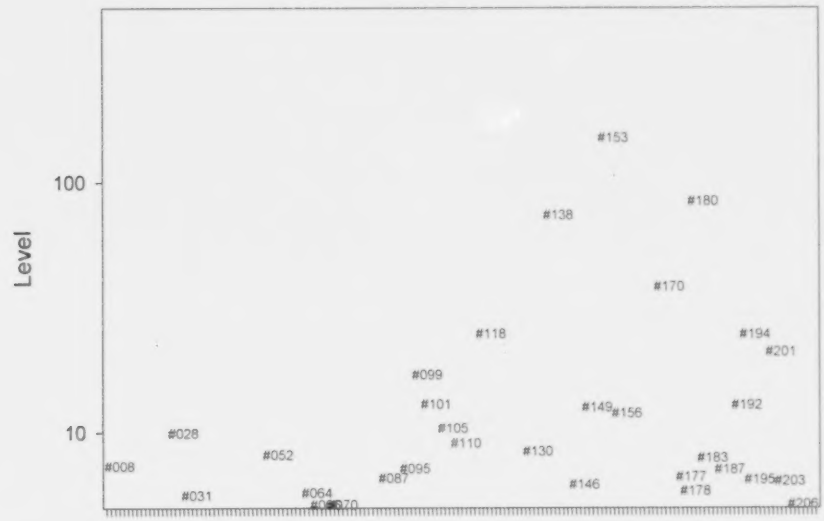

Figure 3-1 PCB Congener Patterns in Deer Muscles, 1999 and 2001

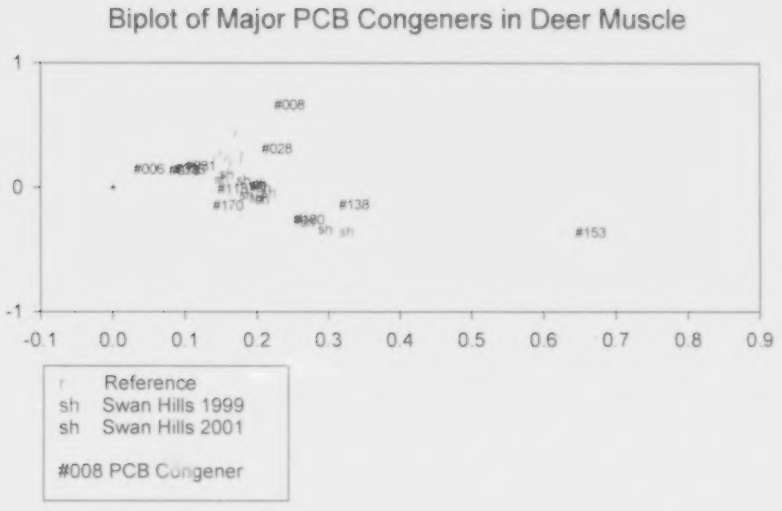

Figure 3-2 PCB Congener Patterns in Deer Muscles in the Study and Reference Areas

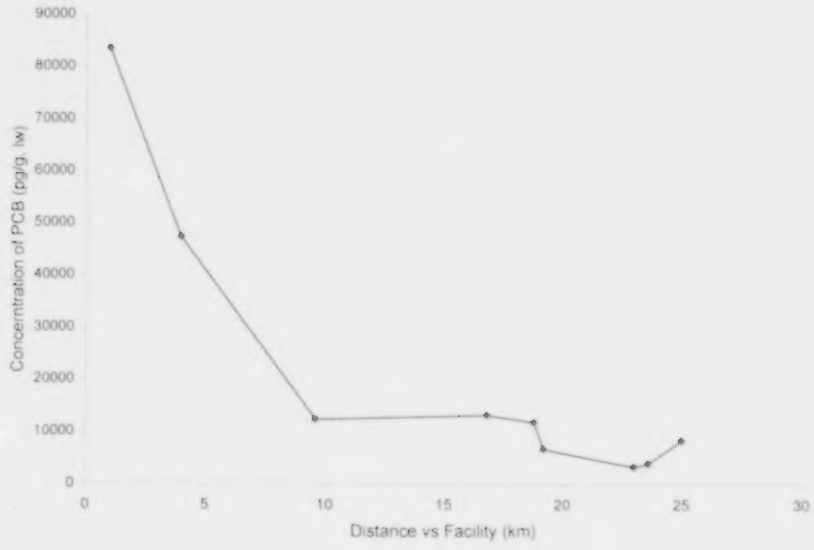

Figure 3-3 PCB Levels in Deer Muscles vs. Distance to the Facility, 1999

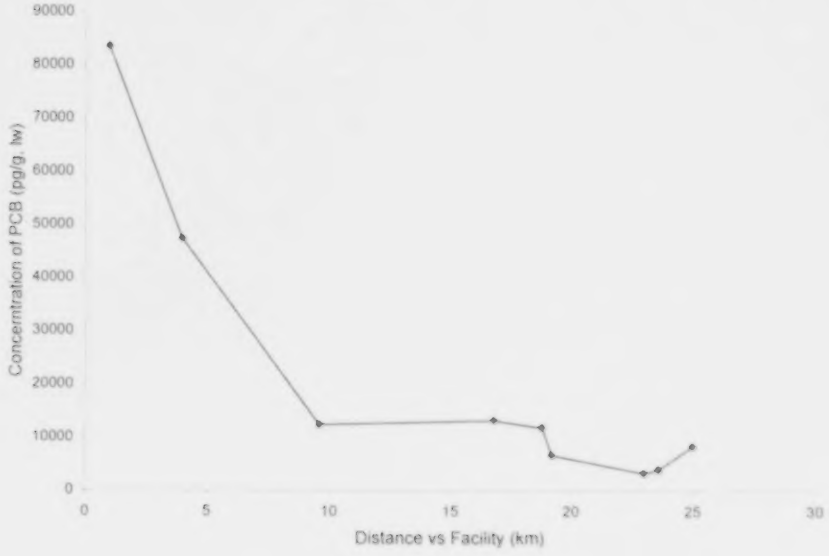

Figure 3-4 PCB Levels in Deer Livers vs. Distance to the Facility, 1999

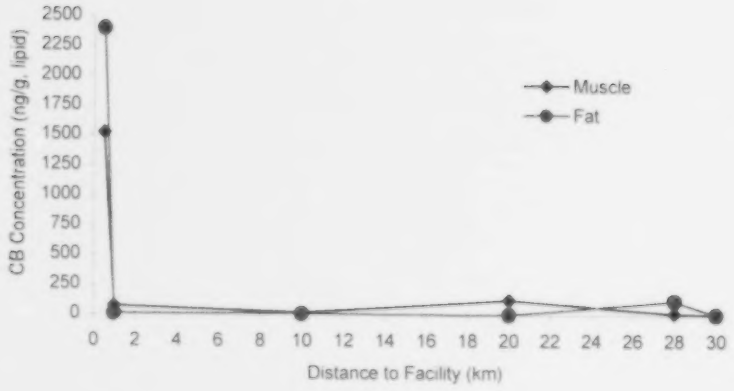

Figure 3-5 PCB Levels in Deer Muscles and Fats vs. Distance to the Facility, 2001

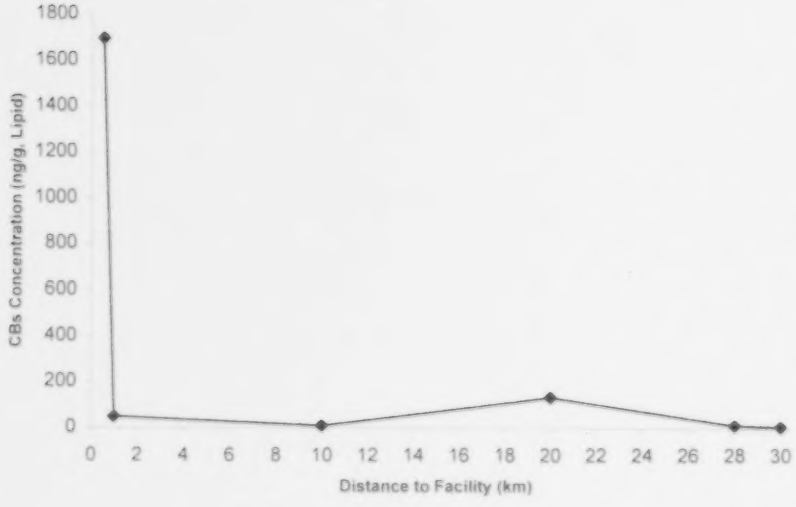

Figure 3-6 PCB Levels in Deer Livers vs. Distance to the Facility, 2001

3.2.3 PCDD/Fs: 1999-2001

The mean values of ∑PCDD/Fs and their homologues are summarized in Table 3-5.

Table 3-5 Mean of PCDD/Fs and Homologues in Deer (pg/g, lipid basis)

Parameter	2001 Study Area (N=6)			1999 Study Area (N=9)		1999 Control Area (N=10)	
	Liver	Muscle	Fat	Liver	Muscle	Liver	Muscle
Lipid content (%)	3.69	2.53	65	3.00	2.3	3.7	3.5
2,3,7,8-TCDD	5.7	<0.06	0.29	2.2	<0.08	<0.08	<0.08
1,2,3,7,8-PeCDD	31.3	<0.08	0.92	28.9	<0.08	2.16	<0.08
1,2,3,4,7,8-HxCDD	46.1	<0.10	0.76	44.2	<0.10	4.56	<0.10
1,2,3,6,7,8-HxCDD	47.9	<0.10	1.26	79.5	8.92	10.31	6.52
1,2,3,7,8,9-HxCDD	10.3	<0.10	0.31	29.4	<0.10	2.87	<0.10
1,2,3,4,6,7,8-HpCDD	210	3.89	1.81	258	5.82	40.88	7.90
OCDD	285	25.56	3.30	295	81.82	53.87	38.98
2,3,7,8-TCDF	147	7.99	10.77	17.5	1.00	<0.05	<0.05
1,2,3,7,8-PeCDF	8.5	1.42	2.92	4.4	<0.06	<0.06	<0.06
2,3,4,7,8-PxCDF	24155	54.49	76.95	1842	6.68	6.00	<0.06
1,2,3,4,7,8-HxCDF	2576	8.13	9.92	218	0.90	2.95	<0.08
1,2,3,6,7,8-HxCDF	992	1.88	3.05	120	<0.08	2.62	<0.08
1,2,3,7,8,9-HxCDF	1009	<0.08	2.23	96.0	<0.08	1.97	0.27
2,3,4,6,7,8-HxCDF	1.0	<0.08	0.00	0.5	<0.08	<0.08	<0.08
1,2,3,4,6,7,8-HpCDF	386	2.43	1.25	65.6	4.46	5.84	3.80
1,2,3,4,7,8,9-HpCDF	38.6	<0.10	0.06	6.5	<0.10	0.56	<0.10
OCDF	31.6	3.67	0.37	17.8	8.42	3.07	3.82
∑PCDD/Fs (Ind.)	**29980**	**109**	**116**	**3125**	**118**	**138**	**61**
Σ TCDD	5.7	0.2	0.3	5.5	5.4	3.7	3.3
Σ PeCDD	31	<0.08	1.0	28.9	<0.08	2.2	<0.08
Σ HxCDD	104	3.4	3.1	154	11	18	9.7
Σ HpCDD	210	7.7	2.5	271	10	43	15
Σ OCDD	285	25.6	3.3	295	82	54	39
Σ TCDF	161	8.0	14	19	1.0	<0.05	<0.05
Σ PeCDF	24206	60.7	94	1853	7.3	6.0	0.1
Σ HxCDF	4578	10.0	17	436	0.9	7.6	0.8
Σ HpCDF	425	2.5	1.4	76	4.5	6.7	5.1
Σ OCDF	32	3.7	0.4	18	8.4	3.1	3.8
Σ PCDD/Fs (Homo.)	**30038**	**122**	**137**	**3155**	**130**	**144**	**77**
% of ∑PCDD/Fs (Ind.) in Σ PCDD/Fs (Homo.)	99.8	89.9	84.9	99.0	90.8	95.5	79.9

In the 1999 study, all the 2,3,7,8- substituted PCDD/F congeners (17 in total) were detected in the liver samples from the study area. Eight PCDD/Fs congeners were detected in the muscle samples from the study area. OCDD contributed to 70% of the total PCDD/F in the muscle samples from the study area and 64% in the reference area. In the 2001 study, all 17 PCDD/Fs

congeners were detected in the liver and fat samples. Eight of 17 congeners were not detected in muscle samples, including 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF and 1,2,3,4,7,8,9-HxCDF. Means of individual PCDD/Fs congeners accounted for 99.8% of their homologues in the liver samples in the study area and 96% in control areas, 90% in the muscle in the study area and 80% in control areas, and 85% in the fat in the study area.

The concentrations of PCDD/Fs in the liver collected in 2001 were significantly higher than the samples collected in 1999 in the study area and reference areas. The concentration of PCDD/Fs in the muscle was not significantly different in the samples from the study area (1999 and 2001) and control areas (1999). The concentrations of PCDD/Fs were similar in the muscle and fat. The results indicated that PCDD/Fs were mainly concentrated in the liver.

The most predominant congener in all the 2001 samples was 2,3,4,7,8-PeCDF, accounting for 80% of ΣPCDD/Fs in the liver, 66% in the fat and 50% in the muscle (Figure 3-7). Other prevalent compounds in the liver include 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 1,2,3,4,6,7,8-HpCDF and 1,2,3,4,7,8,9-HpCDF.

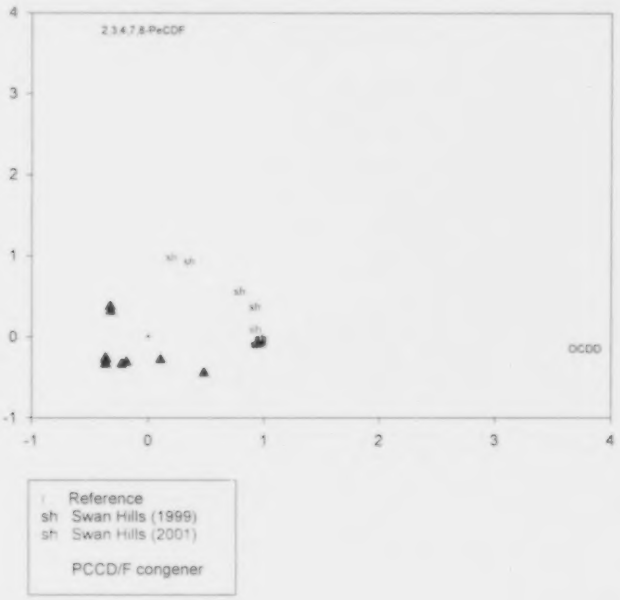

Figure 3-7 PCDD/F Patterns in Deer Muscles in the Study and Reference Area

In comparison with the 1999 results from the reference areas, the most prevalent congeners in the liver were 1,2,3,4,6,7,8-HpCDD (30%) and OCDD (40%). 2,3,4,7,8-PeCDF only accounted for 4% of ΣPCDD/Fs. Therefore, 2,3,4,7,8-PeCDF may be a marker congener present in the

emissions of the special waste treatment facility as it has been observed to be the major congener in soil, vegetation, sediment, fish and voles collected near the facility since 1996.

The concentrations of ΣPCDD/Fs against distance from facility in 1997, 1999 and 2001 studies are summarized in Table 3-6. The highest ΣPCDD/Fs concentrations were detected in the tissue of the two deer collected at a distance of 0.5 km and 1.0 km from the facility in 2001 and 1.0 km and 4.0 km from the facility in 1999. Similar to the 1997 results, the PCDD/Fs concentrations in all the samples decreased with distance from the facility. The mobility of white-tail and mule deer is restricted to a radius of 4 to 5 km in the winter. This finding suggests that contamination has occurred in the ecosystem in the vicinity of the facility and that PCDD/Fs have also accumulated in deer.

Table 3-6 Concentrations of ΣPCDD/Fs in Deer (pg/g) vs. Distance to Facility

Sample ID	Distance to Facility (km)	Liver (wet weight)	Liver (lipid weight)	Muscle (wet weight)	Muscle (lipid weight)	Fat (wet weight)	Fat (lipid weight)
			2001 Results				
Sample 1	0.5	381	10459	1.29	145	90	158
Sample 2	1.0	5754	168749	3.49	478	212	390
Sample 3	10	12	306	0.61	10	11	18
Sample 4	20	6.40	181	0.00	0.00	N/A	N/A
Sample 5	28	5.89	116	0.21	5.28	2	2
Sample 6	30	1.75	73	0.30	19	9	13
			1999 Results				
Sample 1	1.0	638	17618	1.51	98	N/A	N/A
Sample 2	4.0	286	8157	1.01	102	N/A	N/A
Sample 3	10	0.78	496	3.85	114	N/A	N/A
Sample 4	17	19	507	0.53	47	N/A	N/A
Sample 5	19	10	347	0.40	21	N/A	N/A
Sample 6	19	10	279	0.39	23	N/A	N/A
Sample 7	23	5.17	151	0.51	17	N/A	N/A
Sample 8	24	6.39	223	3.87	65	N/A	N/A
Sample 9	25	11	347	8.20	573	N/A	N/A
			1997 Results				
Sample 1	10	459	14340	2.8	122	54	58
Sample 2	20	4955	206442	0.5	83	N/A	N/A
Sample 3	30	23	582	nd	nd	8.9	11

3.2.4 Dioxin-like TEQs: 1999-2001

Mean values of ΣPCBs-TEQ, ΣPCDD/Fs-TEQ and ΣTEQ are presented in Tables 3-7 and 3-8.

Table 3-7 Mean of TEQ in Deer in Study and Reference Areas, 1999 (pg/g, lipid basis)

	Study Area				Reference Area			
	Muscle	%	Liver	%	Muscle	%	Liver	%
CB-77	0.01	0.57	0.02	0.03	0.01	2.98	0.00	0.33
CB-105	0.03	1.78	0.05	0.06	0.01	2.95	0.00	0.29
CB-114	0.02	1.02	0.02	0.03	0.00	0.59	0.00	0.04
CB-118	0.08	4.08	0.12	0.15	0.01	7.02	0.01	0.67
CB-123	0.00	0.07	0.00	0.00	0.00	0.05	0.00	0.01
CB-126	1.35	70.6	83.8	98.6	0.11	58.8	0.99	94.5
CB-156	0.16	8.59	0.30	0.35	0.01	4.41	0.01	0.48
CB-157	0.05	2.61	0.08	0.09	0.02	8.48	0.01	1.05
CB-167	0.00	0.03	0.00	0.00	0.00	0.02	0.00	0.00
CB-169	0.04	2.29	0.32	0.38	0.02	11.5	0.02	2.03
CB-170	0.13	7.03	0.23	0.27	0.00	2.61	0.01	0.54
CB-180	0.02	1.04	0.03	0.04	0.00	0.56	0.00	0.09
CB-189	0.01	0.27	0.01	0.01	0.00	0.01	0.00	0.01
2,3,7,8-TCDD	0.00	0.00	2.23	0.22	0.00	0.00	0.00	0.00
1,2,3,7,8-PeCDD	0.00	0.00	14.45	1.44	0.00	0.00	1.08	15.10
1,2,3,4,7,8-HxCDD	0.00	0.00	4.42	0.44	0.00	0.00	0.46	6.38
1,2,3,6,7,8-HxCDD	0.89	19.3	7.95	0.79	0.65	77.67	1.03	14.45
1,2,3,7,8,9-HxCDD	0.00	0.00	2.94	0.29	0.00	0.00	0.29	4.02
1,2,3,4,6,7,8-HpCDD	0.06	1.26	2.58	0.26	0.08	9.42	0.41	5.73
OCDD	0.08	1.77	0.29	0.03	0.04	4.65	0.05	0.75
2,3,7,8-TCDF	0.10	2.16	1.75	0.18	0.00	0.00	0.00	0.00
1,2 3,7,8-PeCDF	0.00	0.00	0.22	0.02	0.00	0.00	0.00	0.00
2,3,4,7,8-PxCDF	3.34	72.4	921	91.9	0.00	0.00	3.00	42.04
1,2,3,4,7,8-HxCDF	0.09	1.95	21.8	2.17	0.00	0.00	0.30	4.13
1,2,3,6,7,8-HxCDF	0.00	0.00	12.0	1.19	0.00	0.00	0.26	3.68
1,2,3,7,8,9-HxCDF	0.00	0.00	9.60	0.96	0.03	3.28	0.20	2.77
2,3,4,6,7,8-HxCDF	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
1,2,3,4,6,7,8-HpCDF	0.04	0.97	0.66	0.07	0.04	4.53	0.06	0.82
1,2,3,4,7,8,9-HpCDF	0.00	0.00	0.06	0.01	0.00	0.00	0.01	0.08
OCDF	0.01	0.18	0.02	0.00	0.00	0.46	0.00	0.04
ΣPCBs-TEQ[a]	1.91		85		0.19		1.04	
ΣPCDDs/Fs-TEQ[b]	4.61		1002		0.84		7.14	
Σ TEQ	6.52		1087		1.03		8.18	
% of ∑PCBs-TEQ in ∑TEQ		29		8		18		13
% of ∑PCDDs/Fs-TEQ in ∑TEQ		71		92		82		87
% of 2,3,4,7,8-PeCDF in ∑PCDD/Fs-TEQ		72		92		0		42
% of 2,3,4,7,8-PeCDF in Σ TEQ		51		85		0		37
% of PCB-126 in ∑PCBs-TEQ		71		99		59		95
% of PCB-126 in ΣTEQ		21		7.7		11		12

a. WHO-IPCS I-TEFs., b. NATO-CCMS I-TEFs.

Table 3-8 Mean of TEQ in Deer Tissues in Study Area, 2001 (pg/g, lipid basis)

	Muscle	%	Liver	%	Fat	%
CB-77	0.14	0.79	0.03	0.00	0.02	0.04
CB-105	0.37	2.15	0.40	0.02	0.60	1.61
CB-114	0.20	1.13	0.25	0.01	0.36	0.97
CB-118	0.92	5.33	1.29	0.08	1.56	4.19
CB-123	0.01	0.06	0.01	0.00	0.01	0.03
CB-126	9.70	56.4	1660	98.9	23.89	64.2
CB-156	2.73	15.9	5.69	0.34	4.96	13.3
CB-157	0.56	3.25	1.26	0.08	0.88	2.36
CB-167	0.00	0.03	0.02	0.00	0.01	0.02
CB-169	0.43	2.49	7.22	0.43	0.59	1.60
CB-170	1.70	9.87	1.72	0.10	3.60	9.67
CB-180	0.40	2.33	0.39	0.02	0.65	1.75
CB-189	0.06	0.35	0.10	0.01	0.08	0.23
2,3,7,8-TCDD	0.00	0.00	5.73	0.05	0.29	0.70
1,2,3,7,8-PeCDD	0.00	0.00	15.65	0.12	0.46	1.09
1,2,3,4,7,8-HxCDD	0.00	0.00	4.61	0.04	0.08	0.18
1,2,3,6,7,8-HxCDD	0.00	0.00	4.79	0.04	0.13	0.30
1,2,3,7,8,9-HxCDD	0.00	0.00	1.03	0.01	0.03	0.07
1,2,3,4,6,7,8-HpCDD	0.04	0.13	2.10	0.02	0.02	0.04
OCDD	0.03	0.09	0.28	0.00	0.00	0.01
2,3,7,8-TCDF	0.80	2.73	14.73	0.12	1.08	2.55
1,2,3,7,8-PeCDF	0.07	0.24	0.43	0.00	0.15	0.35
2,3,4,7,8-PxCDF	27.24	93.3	12077	95.9	38.50	91.1
1,2,3,4,7,8-HxCDF	0.81	2.79	257.6	2.05	0.99	2.35
1,2,3,6,7,8-HxCDF	0.19	0.64	99.17	0.79	0.31	0.72
1,2,3,7,8,9-HxCDF	0.00	0.00	100.9	0.80	0.22	0.53
2,3,4,6,7,8-HxCDF	0.00	0.00	0.10	0.00	0.00	0.00
1,2,3,4,6,7,8-HpCDF	0.02	0.08	3.86	0.03	0.01	0.03
1,2,3,4,7,8,9-HpCDF	0.00	0.00	0.39	0.00	0.00	0.00
OCDF	0.00	0.01	0.03	0.00	0.00	0.00
ΣPCBs TEQ	17		1678		37	
ΣPCDDs/Fs TEQ	29		12589		42	
Σ TEQ	46		14267		79	
% of ∑PCBs-TEQ in ∑TEQ		63		88		53
% of ∑PCDDs/Fs-TEQ in ∑TEQ		37		12		47
% of 2,3,4,7,8-PeCDF in ∑PCDDs/Fs-TEQ		93		96		91
% of 2,3,4,7,8-PeCDF in Σ TEQ		59		85		48
% of PCB-126 in ∑PCBs-TEQ		56		99		64
% of PCB-126 in Σ TEQ		21		12		30

The major component of the ΣTEQ in all samples from the study area in 1999 and 2001 studies was 2,3,4,7,8-PeCDF, which accounted for 84% - 85% of ΣTEQ in the liver and 51% - 59% in the muscle samples. Very high levels of CB-126-TEQ (1660 pg/g, lipid basis) were observed in the livers in the 2001 study area as compared to 83 pg/g, lipid basis, in the 1999 study area and 0.99 pg/g, lipid basis, in reference areas. PCB-126 TEQ accounted for 99% of ΣPCBs-TEQ and 12% of ΣTEQ in the liver, 56% of ΣPCBs-TEQ and 21% of ΣTEQ in the muscle and 64% of ΣPCBs-TEQ and 30% of ΣTEQ in the fat. In the reference areas, 1,2,3,6,7,8-HxCDD and CB-126 were the major contributors in the muscle samples, accounting for 58% and 12% of ΣTEQ, respectively. Major congeners contributing to ΣTEQ in the liver were 2,3,4,7,8-PeCDF (36%), 1,2,3,6,7,8-HxCDD (13%) and 1,2,3,7,8-PeCDD (13%).

2,3,4,7,8-PeCDF and CB-126 may be marker congeners present in the emissions of the special waste treatment facility as it has been observed to be a major congener in soil, vegetation, sediment, fish and voles collected near the facility since 1996.

3.3 Summary

Overall levels of ΣPCBs in the liver and muscle in 2001 and 1999 declined as compared to the 1997 levels (Figure 3-8 A and Figure 3-8 B). The levels of ΣPCBs TEQ increased in the liver in 2001, as compared to those in the 1997 and 1999 studies. Overall, levels of ΣPCBs TEQ in the muscle in 2001and 1999 declined as compared to the 1997 levels.

Figure 3-8 Summary of PCBs in Deer Tissue Monitoring

Overall levels of ΣPCDD/Fs in the liver declined in 2001 as compared to the 1997 levels (Figure 3-9 A) but increased as compared to 1999 levels. The ΣPCDDs/Fs levels in the muscle in 1999 and 2001 increased as compared to the 1997 levels (Figure 3-9 B). The levels of ΣPCDD/Fs TEQ increased in the liver and muscle in 2001 compared to those in the 1997 and 1999 studies.

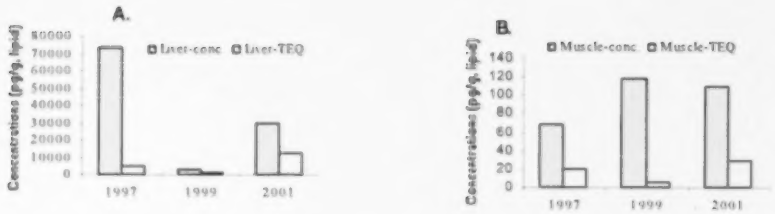

Figure 3-9 Summary of PCDD/Fs in Deer Tissue Monitoring

Distribution patterns of ∑PCDD/Fs, ∑PCBs and ∑TEQ in the 1999 and 2001 studies were consistent with those observed in the 1997 study and the annual monitoring programs conducted by the company. The inverse relationship between concentrations and distance to the facility suggests that the contamination is limited to the immediate vicinity of the facility.

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4. Fish Tissue Monitoring

4.1 Materials and Methods

4.1.1 Field Collection

1997

Field collection was carried out during June and July, 1997. A total of 16 brook trout were collected from Chrystina Lake, about 1.5 km northeast of the facility, with an average age of 2.0 years (a range of 1.0 to 3.0) and average weight of 112 g (a range of 60 to 229). Seventeen northern pike were collected from Roche Lake, about 20 km east of the facility, with an average age of 4.4 years (a range of 3.0 to 6.0) and average weight of 1.2 kg (a range of 0.8 to 2.3). A total of 32 northern pike were collected from Chip Lake (a reference lake) with an average age of 5.4 years (a range of 4 to 7) and average weight of 1.1 kg (a range of 0.6 to 1.5). Both muscle and liver were analyzed. For Chrystina and Roche Lake samples, each composite sample was formed from four (or five) fish from a single species from the same lake with approximately the same length and weight. For Chip Lake samples, each composite sample was formed from 6 or 7 fish. A total of 26 composite samples were formed. All specimens were kept frozen at -20° C prior to laboratory analysis.

2000

Field collection was carried out during August and September, 2000. A total of 12 brook trout were collected from Chrystina Lake, about 1.5 km northeast of the facility, with an average total length of 295 mm and average weight of 318 g. All samples were kept frozen at -20° C prior to contaminants analysis.

4.1.2 PCBs and PCDD/Fs Analysis

1997

PCDD/Fs and PCBs determinations for all samples were performed by the MAXXAM Laboratory, Mississauga, Ontario. Analytical methods and QA/QC assurance were described in Environmental Canada EPS 1/RM/23 (1992), Environmental Canada AMD 96-05 (1996) and USEPA Method 1613 (1994). Each sample was homogenized and subsampled for analysis. Prior to the initial extraction, samples were fortified with fifteen $^{13}C_{12}$-labeled PCDD/Fs with the exception of OCDF, and eight $^{13}C_{12}$-labeled PCBs. Samples were digested overnight in concentrated hydrochloric acid and then extracted with 50/50 dichloromethane/hexane for one hour. This extraction was repeated several times. Lipid content was determined gravimetrically from the remaining extract. The extracts were subjected to an acid/base silica cleanup, reconcentrated and split into two equal portions by weight. One portion, for PCDD/F analysis, was cleaned up on alumina following the standard operating procedure for PCDD/PCDFs. The PCB portion was cleaned up on a modified alumina column. Extracts were analyzed separately

for PCBs and PCDD/Fs on an Autospec Ultima High Resolution Mass Spectrometer, interfaced with a Hewlett Packard Gas Chromatograph. PCBs were separated at EI 8,000 mode and PCDD/Fs at EI 10,000 mode. Fused silica capillary columns (60 meter, 0.25 mm ID, 0.25 μm film thickness) were used for determining PCDD/Fs and PCB congeners, respectively. Injector temperature was 265 °C. The total time of the GC run was 50 min. Congeners were detected in the selected ion monitoring (SIM) mode.

2000

PCDD/Fs and PCBs determinations for all samples were performed by the Fisheries and Oceans Regional Dioxin Laboratory at the Institute of Ocean Sciences in Sidney, British Columbia. The methodologies used to process the samples, the criteria used for identification and quantification and the quality assurance/quality control protocols followed are described in detail elsewhere (Ikonomou et al. 2001). From each sample four aliquots were collected from the carbon-fibre fractionation, the last part of the sample clean-up process. Fraction-I contained the di-ortho PCBs, fraction-II the mono-ortho PCBs, fraction-III the non-ortho PCBs and fraction-IV the PCDDs and PCDFs. In fractions I to III all the possible 209 PCB congeners were measured with minimum isomeric interference. Analyses of all fractions were conducted by high-resolution gas chromatograph/high-resolution mass spectrometry (HRGC/HRMS). For all analyses the MS was operated at 10000 resolution under positive EI conditions and data were acquired in the Single Ion Monitoring Mode (SIM). The concentrations of identified compounds and their minimum detection limits (MDLs) were calculated by the internal standard method using mean relative response factors determined from calibration standard runs, made before and after each batch of samples was run. Detection limits range from 0.01 to 0.12 pg/g for PCDDs/Fs, 0.04 to 0.08 pg/g for non-ortho PCBs, 0.1 pg/g for mono-ortho PCBs and 0.1 to 0.2 pg/g for di-ortho PCBs.

4.2 Results and Discussions

4.2.1 PCBs and PCDD/Fs –1997

Summary of PCB and PCDD/F levels in all species and locations are presented in Table 4-1. $\sum PCB_{congener}$ and $\sum PCCD/F_{congener}$ concentrations in brook trout from Chrystina Lake were significantly higher ($p<0.01$) than those in northern pike from Roche and Chip lakes, which did not differ from each other. Under normal circumstance, northern pike, a predator, would be expected to have higher contaminant concentrations than brook trout which feed on planktonic invertebrates (Kidd et al. 1995). Pike with larger size and greater age would also contribute to this effect. The lower contaminant values in pike from Roche and Chip lakes indicate very low contaminant background. In contrast, brook trout caught for chemical analysis were smaller and younger. Concentrations of these contaminants were generally one order of magnitude higher in brook trout compared to northern pike.

Table 4-1 Summary of PCB and PCDD/F Levels in Fish Samples, 1997

Tissue	Muscle			Liver		
Lake	Chrystina	Roche	Chip	Chrystina	Roche	Chip
Fish species	*brook trout*	*northern pike*	*northern pike*	*brook trout*	*northern pike*	*northern pike*
Sample size (composite)	4	4	5	4	4	5
Detects of PCBs	4	4	3	4	4	5
Detects of PCDD/Fs	4	4	3	4	3	4
Lipid content (%)	0.4	0.6	0.3	N/A	4.3	3.6
Mean of $\sum PCB_{congener}$ (µg/kg, ww) (range)	18[a] (9.7-27)	1.0 (0.3-2.8)	0.25 (0.04-0.7)	70[a] (41-117)	7.8 (1.2-14)	6.4 (3-18)
% of $\sum PCB_{congener}/\sum PCB_{homologs}$	34	38	19	32	31	34
% of measured congeners from each homologue group* / $\sum PCB_{congener}$						
di-CB	0.3	0	2	0.2	1	0.9
tri-CB	1.4	2	7	2	1.6	4
tetra-CB	10	5	0	10	8	7
penta-CB	20	25	19	20	23	25
hexa-CB	48	48	52	47	47	50
hepta-CB	19	18	4	19	18	12
octa-CB	0.9	0.8	0	1	1	0.9
deca-CB	0.2	1	16	0.2	0.3	0.2
Mean of $\sum PCDD/F_{congener}$ (ng/kg, ww) (range)	22[a] (12-30)	0.93 (0.7-1.1)	0.68 (ND-1.2)	227[a] (55-351)	1.2 (ND-2)	7.5 (ND-19)
Mean of TEQ (ng/kg, ww)						
$\sum$ *non-ortho* CB**	9.4	0.22	0	44	2.9	2.2
$\sum$ *mono-ortho* CB**	0.2	0.01	0.002	0.7	0.1	0.1
$\sum$ *di-ortho* CB **	0.1	0.006	0.0001	0.3	0.03	0.02
$\sum$ PCDD/F	2.7[a]	0.003	0.002	16[a]	0.2	0.1
$\sum$ Dioxin-like compounds*** (range)	12.4[a] (6-19)	0.24 (0.01-1)	0.004 (ND-0.007)	61[a] (24-107)	3.2 (0.7-5.5)	2.4 (1-7)
% of $\sum PCB/\sum$Dioxin-like	78	98	56	73	93	95
% of $\sum$PCDD-F/$\sum$Dioxin-like	22	2	44	27	7	5

a: Difference statistically significant at $p<0.01$

* congener #8 in di-CB, #18, #28, #33, #37 in tri-CB, #44, #49, #52, #70, #74, #77, #81 in tetra-CB, #87, #99, #101, #114, #118, #119, #123, #126 in penta-CB, #128, #137, #138, #151, #153, #156, #157, #158, #167, #168, #169 in hexa-CB, #170, #177, #180, #183, #187, #189, #191 in octa-CB, NA in nona-, and #209 in deca-CB.

** *non-ortho-* = CB (nos.) 77, 126, 169, *mono-ortho-* = CB (nos.) 105, 114, 118, 123, 156, 157, 167, 189, *di-ortho-* = CB (nos.) 170, 180

*** Sum of $\sum$CB-TEQ and $\sum$PCDD/F-TEQ

A wide range of individual PCB congeners was detected. Hexachlorobiphenyl (about 50%) was a prevalent homologue group while di-, tri-, tetra-, octa- and deca- chlorobiphenyls were minor constituents across all species and locations. CB 101, 118, 138, 153, and 180 constituted 50% of $\sum PCB_{congener}$ for brook trout, 60% for pike liver and 70% for pike muscle. The findings also are consistent with the results in the company's monitoring programs and two other relevant studies in which CB 138, 153 and 180 were found as major contributors in vegetation, soil, spruce needle and snow pack near the facility.

The majority of ∑dioxin-like TEQ in all samples was due to PCBs. The most important contributors were *non-ortho* congeners which accounted for 78% of ∑dioxin-like TEQ in brook trout muscle, 73% in brook trout liver, over 90% in pike with the exception of pike muscle from Chip Lake. CB 169 alone contributed 58% to 70% of ∑dioxin-like TEQ in brook trout liver and muscle, respectively. CB 126 was not detected in northern pike. A major contributor in pike muscle from Chip Lake was CB 118, contributing 53% to ∑dioxin-like TEQ. This finding is comparable to the results of the company's monitoring program in which elevated levels of *non-ortho* PCBs were found in Labrador tea leaves, live moss and soils.

Combustion processes could be the source of the increased environmental levels of the coplanar congeners characterized by 3,3',4,4' substitution such as 169, 126, 77, 105, 156, 157, 170 and 189 (Brown et al. 1995, Kimbrough 1995). The air emission from the facility may contribute to higher levels of *non-ortho* PCBs in brook trout.

2,3,7,8-tetra CDF and 2,3,4,7,8-penta CDF were prevalent in brook trout, accounting for 22% (muscle) to 27% (liver) of ∑dioxin-like TEQ. OCDD and 1,2,3,7,8-penta CDF represented 44% of ∑dioxin-like TEQ in pike muscle from Chip Lake. PCDD/Fs were minor constituents in pike liver and muscle from Roche Lake and pike liver from Chip Lake. 2,3,7,8-TCDD was not detected among species and locations at detection limits of 0.5 ng/kg whole weight. The patterns of PCDD/Fs for most incineration sources are likely to include almost every congener (Hallikainen et al. 1997).

2,3,7,8-TCDF was observed in northern pike in northern Alberta and Northwest Territories (Muir, et al. 1997, Pastershank et al. 1996, Sanderson et al. 1997). The results from the company's environmental monitoring program showed that the high levels of 2,3,7,8-tetra CDF and 2,3,4,7,8-penta CDF were measured in Labrador tea leaves, live moss, wild game and voles near the facility, with TCDF predominating in tea leaves and live moss and 2,3,4,7,8-penta CDF in wild game and voles. The results are consistent with those from the current study in which the most prominent congeners in brook trout were 2,3,7,8-TCDF and 2,3,4,7,8-penta CDF. The comparable PCB and PCDD/F profiles suggested that air emission from the facility could be attributed to the elevated levels of PCBs and PCDD/Fs in brook trout from Chrystina Lake.

4.2.2 PCDD/Fs - 2000

The mean values of ∑PCDD/Fs are summarized in Table 4-2. Five PCDD/F congeners were detected in brook trout muscle tissue from Chrystina Lake and 14 in the liver. The mean concentration of ∑PCDD/Fs in the muscle in 2000 was 1.07 pg/g (wet weight) and 288 pg/g (lipid basis), which significantly declined as compared to those in 1997 (22 pg/g, wet weight and 5500 pg/g, lipid basis) (AHW, 1997). The mean value of ∑PCDD/Fs in the liver was 7.33 pg/g, wet weight and 121 pg/g, lipid basis, which was significantly lower as compared to those in brook trout from Chrystina Lake collected in 1997 (227 pg/g, wet weight. Lipid basis data are not available). The levels of ∑PCDD/Fs in 2000 were similar to those in northern pike from two reference lakes (0.68-0.93 pg/g, wet weight in muscle and 1.2-7.5 pg/g, wet weight in the livers).

Table 4-2 Summary of Mean of PCDD/Fs Levels in Fish (pg/g, lipid basis)

Parameter	Muscle		Liver	
	Conc.	%	Conc.	%
Lipid content		0.42		5.98
2,3,7,8-TCDD	<0.06	0.00	1.02	0.85
1,2,3,7,8-PeCDD	<0.08	0.00	1.43	1.18
1,2,3,4,7,8-HxCDD	<0.10	0.00	1.67	1.38
1,2,3,6,7,8-HxCDD	32.03	11.12	12.75	10.53
1,2,3,7,8,9-HxCDD	<0.10	0.00	1.63	1.34
1,2,3,4,6,7,8-HpCDD	16.68	5.79	9.53	7.87
OCDD	129.09	44.80	38.62	31.88
2,3,7,8-TCDF	104.64	36.31	34.96	28.86
1,2,3,7,8-PeCDF	<0.06	0.00	1.22	1.01
2,3,4,7,8-PxCDF	5.73	1.99	7.67	6.33
1,2,3,4,7,8-HxCDF	<0.08	0.00	<0.12	0.00
1,2,3,6,7,8-HxCDF	<0.08	0.00	<0.12	0.00
1,2,3,7,8,9-HxCDF	<0.08	0.00	1.31	1.08
2,3,4,6,7,8-HxCDF	<0.08	0.00	<0.12	0.00
1,2,3,4,6,7,8-HpCDF	<0.10	0.00	3.04	2.51
1,2,3,4,7,8,9-HxCDF	<0.10	0.00	1.79	1.48
OCDF	<0.12	0.00	4.50	3.71
∑PCDD/Fs (Ind.)	**288**	**100**	**121**	**100**
ΣTCDD	13.76	4.29	4.56	3.39
ΣPeCDD	<0.08	0.00	1.43	1.07
ΣHxCDD	39.04	12.17	19.05	14.19
ΣHpCDD	28.39	8.85	14.85	11.06
ΣOCDD	129	40.25	38.62	28.76
ΣTCDF	105	32.66	35.65	26.55
ΣPeCDF	5.66	1.76	9.47	7.06
ΣHxCDF	<0.08	0.00	1.31	0.97
ΣHpCDF	<0.10	0.00	4.83	3.59
ΣOCDF	<0.12	0.00	4.50	3.35
ΣPCDD/Fs (Homo.)	**321**	**100**	**134**	**100**
% of ∑PCDD/Fs (Ind.) in Σ PCDD/Fs (Homo.)	90		90	

The prevalent congeners were OCDD and 2,3,7,8 TCDF, accounting for 45% of OCDD and 36% of 2,3,7,8TCDF in the muscle and 31% and 27% in the liver (Figure 4-1). The pattern in fish tissue samples was different than in deer tissue samples. The major contributor in deer samples was 2,3,4,7,8-PxCDF.

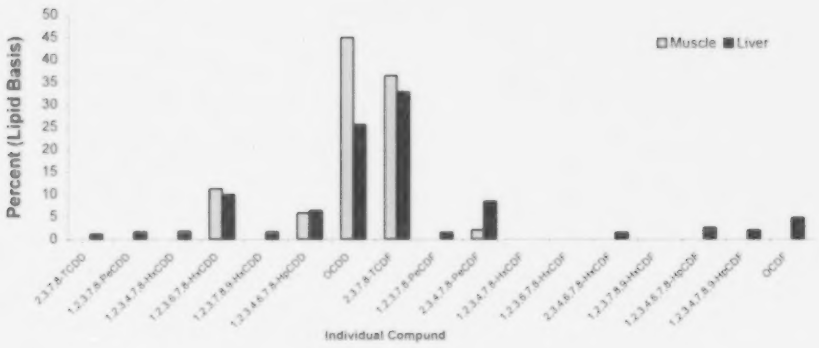

Figure 4-1 Pattern Distribution of PCDD/Fs Congeners in Fish Tissue Samples

4.2.3 PCBs - 2000

The mean values of ∑PCBs and their homologues are summarized in Table 4-3 and 4-4. The mean concentration of ∑PCBs was significantly decreased in the muscle (7455 ng/g, lipid basis) as compared to those in 1997 (16041 ng/g, lipid basis in the muscle). The liver data for 1997 were not available, so a comparison could not be made.

Table 4-3 Mean of PCBs Homologues in Fish Muscle Samples (ng/g, lipid basis)

Group	Conc.	%	Group	Conc.	%
Non-ortho*			***Di-ortho******		
di-CBs	1.94	0.03	*di-CBs*	0.41	0.01
tri-CBs	46.42	0.62	*tri-CBs*	8.79	0.12
tetra-CBs	15.70	0.21	*tetra-CBs*	315.10	4.23
penta-CBs	1.64	0.02	*penta-CBs*	1215.13	16.30
hexa-CBs	0.07	0.00	*hexa-CBs*	2923.18	39.21
Total *non-ortho*	**65.77**	**0.88**	*hepta-CBs*	1460.16	19.59
			octa-CBs	251.26	3.37
			nona-CBs	9.19	0.12
Mono-ortho**					
di-CBs	2.20	0.03	*deca-CBs*	0.88	0.01
tri-CBs	65.47	0.88	**Total *di-ortho***	**6184**	**83**
tetra-CBs	475.65	6.38			
penta-CBs	575.74	7.72	**Total PCBs**	**7455**	**100**
hexa-CBs	81.94	1.10			
hepta-CBs	4.19	0.06			
Total *mono-ortho*	**1205**	**16.17**			

Table 4-4 Mean of PCBs Homologues in Fish Liver Samples (ng/g, lipid basis)

Group	Conc.	%	Group	Conc.	%
Non-ortho*			***Di-ortho******		
di-CBs	0.65	0.03	*di-CBs*	0.23	0.01
tri-CBs	1.52	0.07	*tri-CBs*	2.93	0.14
tetra-CBs	1.84	0.09	*tetra-CBs*	49.62	2.32
penta-CBs	0.46	0.02	*penta-CBs*	306.22	14.35
hexa-CBs	0.03	0.00	*hexa-CBs*	1002.02	46.95
Total *Non-ortho*	**4.50**	**0.21**	*hepta-CBs*	431.74	20.23
			octa-CBs	77.11	3.61
			nona-CBs	2.10	0.10
Mono-ortho**					
di-CBs	1.50	0.07	*deca-CBs*	0.14	0.01
tri-CBs	17.20	0.81	**Total *di-ortho***	**1872**	**87.7**
tetra-CBs	46.42	2.17			
penta-CBs	167.12	7.83	**Total PCBs**	**2134**	**100**
hexa-CBs	24.31	1.14			
hepta-CBs	1.05	0.05			
Total *mono-ortho*	**257.6**	**12.07**			

* Non-ortho CBs: di- (no.11-14), tri- (no. 35-39), tetra- (no. 77-81), penta- (no. 126, 127) and hexa- (no. 169). ** *Mono-ortho* CBs: di- (no.5-9), tri- (no. 20-23, 25-26, 28-29, 31, 33-34), tetra- (no. 55-58, 60-61, 63, 66-67, 68, 70, 72, 74, 76), penta- (no. 105, 107, 108, 111,114, 118, 120, 122-124), hexa- (no. 156, 157, 159, 162, 167) and hepta- (no.189). *** *Di-ortho* CBs: di- (no.4, 10), tri- (no. 16-19, 24, 27, 30, 32), tetra- (no. 40-54, 59, 62, 64, 69, 71, 73, 75), penta- (no. 82-104, 109-110, 112-113, 115-117, 119, 121, 125), hexa- (no. 128-155, 158, 160, 161, 163-166, 168), hepta- (no. 170-188, 190-193), octa- (no. 194-205), nona- (no.206-208) and deca- (no. 209).

The distribution pattern of PCBs is shown in Figure 4-2. The dominant PCB congeners were CB153 and CB138, accounting for 13% to 16% of ∑PCBs in the muscle and liver and 10% to 12% of ∑PCBs in the muscle and liver, respectively. The concentrations of CB 153 were 967 ng/g, lipid basis, in muscle samples and 332 ng/g, lipid basis, in liver samples. The concentrations of CB 138 were 765 ng/g, lipid basis, in muscle samples and 253 ng/g, lipid basis, in liver samples. The prevalent homologue groups were penta-CBs, hexa-CBs and hepta-CBs in di-ortho CBs in all types of samples. Major contributors in the Chip Lake (a reference lake) were CB 8, CB 18, CB 28, and CB32 (Figure 4-3).

4.2.4 Dioxin-like TEQs - 2000

The mean values of ∑TEQ are summarized in Table 4-5. The mean concentrations of ∑TEQ were decreased in the muscle (0.93 pg/g, wet weight and 259 pg/g, lipid basis) and liver (5.7 pg/g, wet weight and 81.6 pg/g, lipid basis) as compared to those in 1997 (12.4 pg/g, wet weight and 3 100 pg/g, lipid basis in the muscle and 61 pg/g, wet weight in the liver).

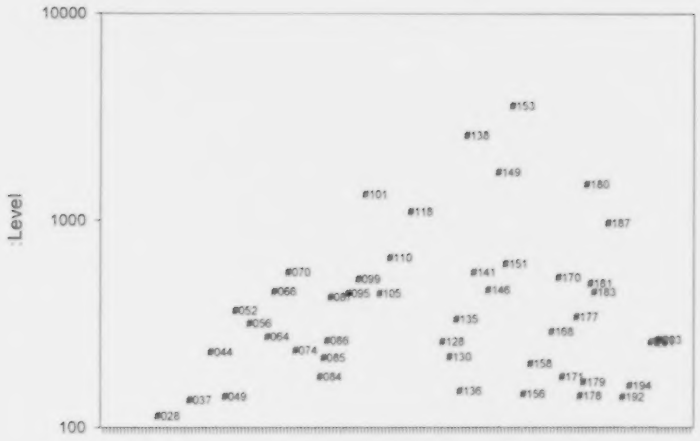

Figure 4-2 Distribution Patterns of PCBs in Fish Muscle Samples

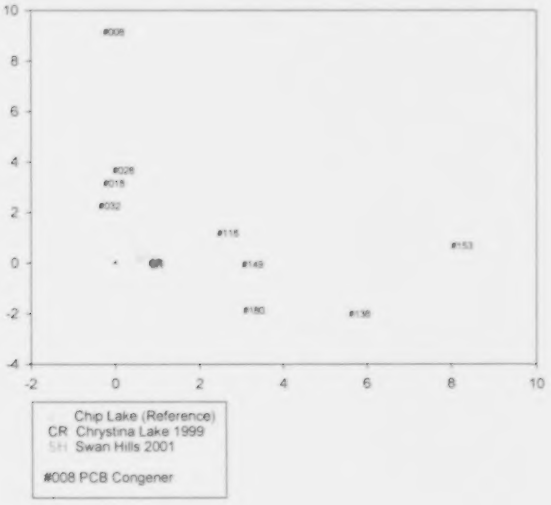

Figure 4-3 Distribution Patterns of PCBs in Fish Muscles in Study and Reference Lakes

Table 4-5 Mean of TEQ in Brook Trout in Chrystina Lake, 2000 (pg/g, lipid basis)

	Muscle	%	Liver	%
CB-77	6.93	2.86	0.81	1.14
CB-105	15.72	6.49	4.53	6.41
CB-114	4.75	1.96	1.45	2.06
CB-118	37.56	15.51	10.65	15.08
CB-123	0.56	0.23	0.18	0.26
CB-126	122.78	50.70	38.13	53.99
CB-156	24.78	10.23	7.10	10.05
CB-157	4.08	1.68	1.20	1.70
CB-167	0.22	0.09	0.07	0.10
CB-169	0.72	0.30	0.29	0.41
CB-170	18.84	7.78	4.75	6.72
CB-180	4.82	1.99	1.36	1.93
CB-189	0.42	0.17	0.11	0.15
2,3,7,8-TCDD	0.00	0.00	1.02	9.27
1,2,3,7,8-PeCDD	0.00	0.00	0.72	6.48
1,2,3,4,7,8-HxCDD	0.00	0.00	0.17	1.51
1,2,3,6,7,8-HxCDD	3.20	19.03	1.28	11.54
1,2,3,7,8,9-HxCDD	0.00	0.00	0.16	1.47
1,2,3,4,6,7,8-HpCDD	0.17	0.99	0.10	0.86
OCDD	0.13	0.77	0.04	0.35
2,3,7,8-TCDF	10.46	62.18	3.50	31.63
1,2,3,7,8-PeCDF	0.00	0.00	0.06	0.55
2,3,4,7,8-PxCDF	2.87	17.03	3.83	34.69
1,2,3,4,7,8-HxCDF	0.00	0.00	0.00	0.00
1,2,3,6,7,8-HxCDF	0.00	0.00	0.00	0.00
1,2,3,7,8,9-HxCDF	0.00	0.00	0.13	1.18
2,3,4,6,7,8-HxCDF	0.00	0.00	0.00	0.00
1,2,3,4,6,7,8-HpCDF	0.00	0.00	0.03	0.27
1,2,3,4,7,8,9-HpCDF	0.00	0.00	0.02	0.16
OCDF	0.00	0.00	0.01	0.04
ΣPCBs TEQ	242		70	
ΣPCDD/Fs TEQ	17		11	
Σ TEQ	259		81	
% of ∑PCBs-TEQ in ∑TEQ	94		87	
% of ∑PCDD/Fs-TEQ in ∑TEQ	6		13	
% of 2,3,7,8-TCDF in ∑PCDD/Fs-TEQ	63		32	
% of 2,3,7,8-TCDF in ΣTEQ	4		4	
% of PCB-126 in ∑PCBs-TEQ	51		54	
% of PCB-126 in Σ TEQ	48		47	

The majority of ∑TEQ in all the samples was due to PCBs (94% in the muscle and 87% in the liver). The most important contributor was CB-126, accounting for 51% and 54% of ∑PCB-TEQ in the muscle and liver, respectively. CB-126 also accounted for 48% and 47% of ∑TEQ in the

muscle and liver, respectively. 2,3,7,8 TCDF and 2,3,4,7,8 PeCDF were prevalent in brook trout, accounting for 63% and 22% of ∑PCDD/F-TEQ in the muscle and 32% and 37% in the liver. However, they were not major contributors of ∑TEQ (4% and 1.5% of ∑TEQ in the muscle, and 4% and 5% in the liver). The findings are comparable to the results of the annual environmental monitoring program for the Special Waste Treatment Facility in which elevated levels of CB-126 TEQ, 2,3,7,8TCDF TEQ and 2,3,4,7,8 PeCDF TEQ were found in Labrador tea leaves, live moss and soils.

Combustion processes could be the source of the elevated environmental levels of the coplanar congeners characterized by 3,3',4,4' substitution such as CB77, CB126, CB169, CB105, CB156, CB157, CB170 and CB189. The comparable PCBs and PCCD/Fs profiles suggested that the air emission from the facility may contribute to the elevated levels of PCBs and PCDD/Fs in brook trout from Chrystina Lake.

4.3 Summary

The mean concentrations of ∑PCDD/Fs, ∑PCBs and ∑TEQ in the muscle and liver samples in brook trout from Chrystina Lake in 2000 were significantly declined as compared to those in 1997.

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5. Estimation of Daily Intake and Exposure Ratio

5.1 Materials and Methods

Diet and Activity Survey - 1997

A diet and activity survey was conducted through telephone interviews during March and April 1997. The survey was divided into two phases. Three hundred and twenty-seven of 370 respondents (88%), including 12 aboriginal people, participated in the first telephone interview. A second telephone interview was then conducted with 100 participants selected from those who had participated in the first telephone interview. Participants were asked to recall their consumption of wild game and fish and their outdoor recreational activities within a 100 km radius of the facility for the previous 12 months. Specifically, the initial survey was used to determine types of outdoor activities within the study area; frequency, duration and amount of wild game and fish consumption; and the respondents' awareness of and adherence to the existing food consumption advisory. The second survey requested demographic characteristics (age, gender, ethnic group, weight and height, occupation, duration of residency, number of persons in the household); proportion of activity time spent indoors and outdoors and detailed information about outdoor activities; detailed information about daily food consumption including consumption of wild game, fish and wild fruit, vegetables and herbs, and cooking and preparation techniques for wild game and fish; and more detailed information about lifestyle (use of alcohol and cigarettes, health conditions and perception of the current health advisory).

Estimates of Daily Intake and Exposure Ratio

Estimated daily intake (EDI) was calculated as follows:

$$EDI = C * IR * BF/BW$$

C is measured concentrations of contaminants, IR is food consumption rate, BF is bioavailability factor (assuming 100%), and BW is average body weight (73 kg for Albertans).
Exposure ratios (ER) were calculated by using the following equation:

$$ER = EDI/TDI$$

The tolerable daily intakes (TDI) are 1 μg/kg/d for PCBs and 10 pg/kg/d for TCDD.

5.2 Results and Discussions

5.2.1 Diet and Activity Survey: 1997

A total of 123 (38%) respondents had consumed wild game taken from the study area and 127 (39%) had consumed fish (Table 5-1). Moose, deer and grouse are the most common wild game for consumption. The most commonly consumed fish species were walleye, northern pike, perch, brook trout, lake whitefish and arctic grayling. The average consumption rate was 35 grams/day of wild game and 15 grams/day of fish. A small proportion of consumers ate a relatively large quantity of local wild game and fish. Aboriginal people may have higher rates of consumption of food from local sources, though specific data for aboriginal people living in the study area are not available.

Table 5-1 Consumption Rate for Wild Game and Fish

Consumption Group*	Wild Game		Fish	
	Mean (g/d)	% consumed (n=123)	Mean (g/d)	% consumed (n=127)
High Intake (>100 g/d)	191	8	167	2
Medium Intake (30-99 g/d)	58	25	47	13
Low Intake (5-29 g/d)	13	31	13	28
Very Low Intake (<4 g/d)	2	36	2	57

* based on consuming muscle portion

5.2.2 Daily Intake and Exposure Ratio: 1997

Estimated daily intake and exposure ratios are presented in Table 5-2. The daily intake of PCBs and PCDD/Fs comes mainly from the diet through commercial food sources, and to a lesser extent, from breathing air and drinking water. The daily intake from background exposure for adult Canadians is estimated to be 2-4 pg PCDD/F/kg/d. The exposure ratio reflects the ratio between the actual level of exposure (external dose) in a particular circumstance and a reference standard associated with observed toxicity in humans or animals. In the current assessment, the estimated daily intake and exposure ratios provide insight into additional exposure that might be expected from consuming local wild game and fish.

The exposure ratios for high and medium consumption groups were greater than one as compared to Health Canada TDI for TCDD at the 90th percentile concentrations of ∑dioxin-like TEQ in deer and brook trout muscles. Around the world, various regulatory guidelines have been developed for TCDD, the most toxic dioxin in the group of PCDD/PCDFs. The guidelines are expressed as a reference dose (RfD) or a tolerable daily intake (TDI), that is, a lifetime daily dose for TCDD which is believed to be without potential health effects to humans. In the past, TCDD has been treated as a threshold carcinogen by some regulatory agencies. Based on this assumption, a value of 10 pg/kg body weight/day has been adopted by Health Canada. Some PCB and PCDD/F congeners produce similar toxic effects to humans and animals as TCDD. The similarity of toxicity between these congeners and TCDD was assessed using toxic equivalency

Table 5-2 Estimated Daily Intake (EDI) and Exposure Ratio (ER)

Consumption Group			High Intake		Medium Intake		Low Intake		Very Low Intake	
Percentile Concentration*			50th	90th	50th	90th	50th	90th	50th	90th
Wild Game	EDI	∑PCB(µg/kg/d)	.02	.2	.005	.06	.001	.01	.0002	.002
	ER	∑PCB	.02	.2	.005	.06	.001	.01	.0002	.002
	EDI	∑TEQ (pg/kg/d)	6.2	175	2.0	53	.4	12	.07	1.8
	ER	∑TEQ**	0.6	**17.5**	0.2	**5.3**	.04	1.2	.007	0.18
Brook Trout	EDI	∑PCB(µg/kg/d)	.04	.08	.01	.02	.003	.007	.0005	.001
	ER	∑PCB	.04	.08	.01	.02	.003	.007	.0005	.001
	EDI	∑TEQ (pg/kg/d)	28	66	8	18	2.2	5.1	.3	.8
	ER	∑TEQ	**2.8**	**6.6**	.8	**1.8**	.2	.5	.03	.08

* concentrations at 50th percentile were 6.5 µg/kg, wet weight, for ∑PCBs and 2.4 ng/kg for ∑TEQ in deer muscle, and 18 µg/kg for PCBs and 12 ng/kg for ∑TEQ in brook trout muscle; concentrations at 90th percentile were 73 µg/kg for PCBs and 67 ng/kg for ∑TEQ in deer muscle, and 36 µg/kg for PCBs and 29 ng/kg for ∑TEQ in brook trout muscle. ** ∑TEQ = ∑dioxin-like TEQ

factors (TEFs). ∑dioxin-like TEQ combines ∑PCB TEQ and ∑PCDD/F TEQ.

Based on concentrations at the 90th percentile of ∑dioxin-like TEQ, a consumption limit was recommended (Table 5-3). These consumption limits provide guidance on the evaluation of the potential risk associated with exposure to PCBs and PCDD/Fs for individuals who consume deer or moose meat taken within a 30 km radius of the facility and/or brook trout from Chrystina lake near the facility. The estimated values represent the amount of meat from deer or moose and from edible portions of brook trout expected to generate a risk no greater than the tolerable daily intake proposed by Health Canada, based on a lifetime of daily consumption at that consumption limit. Because the contaminants tend to accumulate in the internal organs in various animals and the measured levels of the contaminants were very high in the liver samples, people should avoid consumption of viscera from wild game and fish. The current Health Canada TDI for TCDD is based on the potential for cancer. The toxicity of TCDD and related congeners also includes reproductive, developmental and immunotoxic effects. Children and pregnant women or women who are breast-feeding are susceptible groups and should avoid consuming wild game and fish.

Table 5-3 Species-Specific Consumption Limit

Parameter	Wild Game Meat	Fish
Species	deer and moose	brook trout
Location	within 30 km radius of the facility	Chrystina lake
Type of tissue	muscle	muscle
Health Canada TDI for TCDD(pg/kg bw/day)	10	10
Body weight (kg) based on Alberta average	73	73
Consumption limit (oz /week)	3	6
Consumption limit (oz/month)	13	26

Wild game and fish may supplement the diet of a number of people living in the area surrounding the facility. Concern has been raised by both recreational users and traditional users because these two groups consume more wild game and fish than the general population. The balance between nutritional benefits and health risks arising from the consumption of contaminated food is an important consideration in issuing public health advisories.

The current advisories address this issue in three ways. First, the dietary survey attempted to determine the extent of wild game and fish consumption by residents of the study area. Survey results indicate that only a small proportion of people ate wild game and fish caught near the facility at high consumption rates. Second, the advisories provided consumption limits developed from risk estimates rather than an outright ban on consumption. These limits do indicate that wild game and fish may still be safely consumed in moderation. Third, the advisories are restricted to a 30 km radius of the facility in accordance with evidence that contamination with PCBs, PCDDs and PCDFs is restricted to areas near the facility. Therefore, traditional and recreational users can still safely consume wild game and fish obtained from outside the affected area. Finally, it should be noted that the consumption limits provided in the advisories were calculated in reference to uncooked food. Many studies have shown that appropriate food preparation and cooking techniques can reduce the concentrations of PCBs, PCDDs and PCDFs in fish and meat. Thus, techniques such as removing the skin prior to cooking, broiling and baking are recommended for individuals who continue to consume wild game and fish taken from the areas immediately surrounding the facility.

5.2.3 Daily Intake and Exposure Ratio: 1999-2001

Estimated daily intake and exposure ratio from 1999 and 2001 studies are summarized in Table 5-4. The exposure ratios for muscle tissues in wild game and brook trout for all consumption groups were less than one as compared to Health Canada TDI for TCDD. The exposure ratios for liver tissues in wild game from 2001 study for consumption of 2 grams of liver per day were 4-fold higher than the value proposed from Health Canada TDI for TCDD. This increased ratio resulted from very high total dioxin-like TEQ values from one deer caught near the facility.

5.3 Summary

The results from the 1999 and 2001 surveys revealed that overall levels of PCBs and PCDD/Fs in all types of samples except PCDD/Fs in the muscles declined as compared to the 1997 levels. Total TEQ levels in the liver samples increased in 2001. There was a positive correlation between the levels of PCBs and PCDD/Fs and distance from the facility. Exposure ratios were less than one for consuming muscle tissues of wild game and brook trout. The exposure ratios for liver tissues in wild game from 20001 study for consumption of 2 grams of liver per day were 4-fold higher than the value proposed from Health Canada TDI for TCDD. Therefore, there is a need to continue wild game monitoring prior to the review of current food consumption advisories.

Table 5-4 Estimated Daily Intake (EDI) and Exposure Ratio (ER)

Consumption Group			High Intake		Medium Intake		Low Intake		Very Low Intake	
Percentile Concentration*			50th	90th	50th	90th	50th	90th	50th	90th
Wild	EDI	∑TEQ (pg/kg/d)	.09	.67	.03	.20	.006	.05	.001	.007
Game	ER	∑TEQ**	.009	.07	.003	.02	.0006	.005	.0001	.0007
1999										
Wild	EDI	∑TEQ (pg/kg/d)	.14	2.8	.04	0.8	.01	0.19	.001	0.03
Game	ER	∑TEQ	.014	0.28	.004	0.08	.001	0.019	.0001	0.003
2001										
Brook	EDI	∑TEQ (pg/kg/d)	1.7	3.5	.5	.99	.14	.27	.02	.04
Trout	ER	∑TEQ	.17	.35	.05	.099	.014	.027	.002	.004
2000										

* Concentrations at 50th percentile were 0.035 ng/kg for ∑TEQ in 1999, and 0.054 ng/kg for ∑TEQ in 2001 in deer muscle, and 0.77 ng/kg for ∑TEQ in brook trout muscle; Concentrations at 90th percentile were 0.5 ng/kg for ∑TEQ in 1999, and 1.05 ng/kg for ∑TEQ in 2001 in deer muscle, and 1.54 ng/kg for ∑TEQ in brook trout muscle. ** ∑TEQ = ∑dioxin-like TEQ

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6. Background Surveys

6.1 PCDD/Fs, PCBs and PAHs in Sediment

Persistent organic pollutants (POPs) are widely distributed in the environment. Studies in the Canadian Arctic indicate that these contaminants have been accumulating in the Arctic environment from various sources (NCP 1997 and AMAP 1998). Three groups of POPs, polynuclear aromatic hydrocarbons (PAHs), PCDD/Fs, and PCBs are produced by natural processes as well as by anthropogenic activities. PAHs have pyrogenic and biogenic sources and are present in petroleum sources (Yunker et al. 1993 and AMAP 1998). Natural combustion processes such as forest fires produce large quantities of PAHs and some PCDD/Fs (Bumb et al. 1980). Some PCB congeners have been identified from non-commercial PCB mixture sources (Ramamoorthy et al. 1997).

Northern Alberta is located in Western Canada south of the Canadian Arctic and is mainly covered by boreal forest. There are many older, more fire-susceptible forest stands in this region. The warm and dry winter conditions in the Boreal Plain ecozone following El Niño in 1997-1998 became an important factor for the above-average fire activity in northern Alberta during the summer of 1998. In Alberta alone, over 350,000 hectares of forest were burnt in over 50 separate fires. These fast moving fires were among the most extensive ever recorded in North America. The largest and most extensive fire was in the Virginia Hill area, a region that also has many petroleum operation activities. Both natural events and industrial activities could introduce certain quantities of POPs into the environment and into the food chain.

In the fall of 1998, a study was conducted to examine the concentrations of three POPs groups in sediment. The purpose of this study was to explore the characteristics of natural influences (i.e. forest fires) and to trace specific sources of natural and anthropogenic inputs in the Virginia Hill area that is 100 km west of Swan Hills area.

6.1.1 Materials and Methods

Field Collection

Field collection was carried out at three selected sites in Northern Alberta in September 1998. A partially burned site was chosen on a reach of the Sakwatamau River on the edge of the forest fire zone (54° 26.989 N, 116° 07.590 W). A totally burned site was chosen near the middle of the forest fire zone on the Freeman River (54° 35.659 N, 115° 39.694 W). A reference site was chosen on the Little Smoke River in an area that had not experienced forest fires during the year (54° 15.536 N, 117° 06.458 W).

Sampling locations which had a sediment deposition zone in 1-2 feet of water were chosen. For PAH analysis, six representative sampling locations were selected from each river site. For PCDD/F and PCB analysis, five representative sampling locations were selected from each river

site. The top 1 cm of sediment was collected and placed in a clean glass jar. At the totally burned site, some sediment samples contained an abundance of burned pine needles. All samples were kept frozen at -20 °C prior to laboratory analysis.

Chemical Analysis

PAHs

Analysis was performed by Axys Analytical Services Ltd. in Sidney, British Columbia, Canada. A total of 18 parent and 30 alkyl PAH series of some parent PAHs were analyzed in all samples from all sites. A total of 62 non-routine PAHs were analyzed in one sample from each site. The sample (approximately 6 to 7 grams dry weight) was spiked with a suite of deuterium-labelled PAH surrogate standards, ground with anhydrous sodium sulfate, packed into a column and eluted with methanol followed by dichloromethane.

The extract was fractionated and transferred onto a silica gel column. The eluent was extracted by column chromatograph on silica gel into polar PAH and non-polar (alkane) fractions. The polar fraction was analyzed by gas chromatograph/mass spectrometry (GC/MS). Extract was analyzed using Finnigan MAT INCOS 50 Mass Spectrometers, each equipped with a Varian 3400 gas chromatograph, a CTC A200S autosampler and a Prolab data system.

Quality assurance and quality control were monitored on a batch basis by analysis of a method blank, a spiked blank, and a sample duplicate for each batch of eight samples.

PCDD/Fs and PCBs

PCDD/F and PCB determinations for all samples were performed by the Fisheries and Oceans Regional Dioxin Laboratory at the Institute of Ocean Sciences in Sidney, British Columbia, Canada. Samples were analyzed in batches of twelve, each containing a procedural blank, a certified reference material, and nine samples out of which one was analyzed in duplicate.

The methodologies used to process the samples, the criteria used for identification and quantification and the quality assurance quality control protocols followed are described in detail elsewhere (MacDonald et al. 1997). From each sample four aliquots were collected from the carbon-fibre fractionation, the last part of the sample clean-up process. Fraction-I contained the di-ortho PCBs, fraction-II the mono-ortho PCBs, fraction-III the non-ortho PCBs, and fraction-IV the PCDDs and PCDFs. In fractions I to III all the possible 209 PCB congeners are measured with minimum isomeric interference (Ikonomou et al. 1998). Analyses of all fractions were conducted by high-resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS). For all analyses the MS was operated at 10000 resolution under positive EI conditions and data were acquired in the Single Ion Monitoring Mode (SIM).

The concentrations of identified compounds and their minimum detection limits (MDLs) were calculated by the internal standard method using mean relative response factors determined from calibration standard runs, made before and after each batch of samples was run. Detection limits range from 0.01 to 0.12 pg/g for PCDDs/Fs, 0.04 to 0.08 pg/g for non-ortho PCBs, 0.1 pg/g for mono-ortho PCBs and 0.1 to 0.2 pg/g for di-ortho PCBs.

Statistical Analysis

Statistical analysis of individual compounds and congeners and summary measures were performed using one-way Analysis of Variance (ANOVA). A principal components analysis (PCA) was performed for parent PAHs and their alkylated compounds to explore the differences among the profiles between sites.

6.1.2 Results and Discussions

PAHs

A summary of concentrations of the parent PAHs and alkyl PAH homologous series is presented in Table 6-1. Concentrations of the parent PAH totals and alkyl PAH homologous totals, before adjusting total carbon content for each sample were, highest to lowest by location: Site C > Site B > Site A. Three sites had similar sediment properties (64%-70% of sand, 17%-20% of silt and 14%-19% of clay). Total organic carbon (TOC) was 0.55% at the partially burned site and 2.2% at the totally burned and reference sites. Before and after adjusting for TOC, the mean concentrations of the following parent PAHs were higher at the reference site than the totally and partially burned sites: phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzofluoranthenes, benzo[e]pyrene, benzo[a]pyrene, perylene, indeno[1,2,3,cd]pyrene, and benzo[ghi]perylene (Figure 6-1). Levels of naphthalene, indeno[1,2,3,cd]pyrene, and benzo[ghi]perylene were significantly higher at the partially burned site than the other two sites. Perylene was more abundant at all sites, accounting for 50% to 60% of the total parent PAH content. Sulphur compounds - dibenzothiophenes and its homologues were the least abundant.

A predominance of alkylated PAH series over parent PAHs was observed at all sites (Figure 6-2). Phenanthrenes and anthracenes (P/A) homologues were the most abundant alkylated derivatives. The mean concentrations of C1, C2, C3 and C5 P/A were significantly higher at the reference site than the two burned sites. Retene (1-methyl-7-isopropylphenanthrene) and C4 P/A were the most dominating P/A homologues at the totally burned and reference sites. Concentrations of retene and C4 P/A at the totally burned site were the highest, showing a high relative content (45% of the total P/A series) (Figure 6-3). The principal components analysis indicated that retene and C4 P/A were strongly associated with the totally burned site while C1, C2 and C5 P/A were associated with the reference site.

Table 6-1 Levels of Parent and Alkyl PAH Homologues (ng/g. dry weight)[a]

Compounds	Site A N=6	Site B N=6	Site C N=6
Parent PAHs			
Naphthalene*	1.15	2.03	2.30
Acenaphthylene*	nd	nd	nd
Acenaphthene*	nd	0.18	nd
Fluorene*	0.32	0.40	0.18
Phenanthrene*	2.50	4.15	19.0
Anthracene*	0.03	nd	0.32
Fluoranthene*	1.13	3.43	13.7
Pyrene*	2.65	8.38	24.2
Benzo[a]anthracene*	nd	0.60	4.32
Chrysene*	1.92	5.15	14.6
Benzofluoranthenes*	4.92	5.72	5.50
Benzo[e]pyrene*	2.82	5.17	nd
Benzo[a]pyrene*	2.87	8.25	nd
Perylene*	40.7	67.7	227
Dibenzo[ah]anthracene*	0.05	0.23	0.63
Indeno[1,2,3,cd]pyrene*	1.45	3.62	5.37
Benzo[ghi]perylene*	0.37	nd	1.65
∑Parent PAHs *	**62.8**	**145**	**318**
Alkyl Homologues			
Naphthalene	1.15	2.03	2.30
*2-methylnahthalene***	1.46	0.77	6.40
*C1-naphthalenes***	2.67	2.30	16.5
*C2-naphthalenes***	5.57	6.15	62.7
*1,2-imenthylnaphthalene***	0.15	nd	1.93
*2,6-dimethylnaphthalene***	0.52	0.42	4.78
*C3-naphthalenes***	3.23	7.60	88.7
*2,3,6-trimethylnaphtalene***	0.88	1.66	1.88
*2,3,5-trimethylnaphtalene***	0.49	1.37	17.8
*C4-naphtalenes***	nd	1.17	97.7
*C5- naphthalenes***	nd	2.28	56.5
*Cadalene***	1.87	2.30	81.8
∑ Naphthalenes	18	28.0	439

Compounds	Site A N=6	Site B N=6	Site C N=6
Fluorene	0.32	0.4	0.18
*C1-fluorenes***	nd	nd	nd
*C2-fluorenes***	nd	nd	nd
*C3-fluorenes***	nd	27.3	71.5
*C4-fluorenes***	nd	19.7	39.2
*C5-fluorenes***	nd	26.5	56.2
∑ Fluorenes	0.32	73.9	167
Dibenzothiophene*	nd	0.15	nd
*C1-dibenzthiophenes***	0.29	1.28	6.95
C2-dibenzthiophenes**	nd	0.76	0.33
*C3-dibenzthiophenes***	nd	3.23	6.60
∑ Dibenzothiophene	0.29	5.42	13.9
Phenanthrenes/anthracenes	2.53	4.15	19.3
*C1phenanthrenes/anthracenes***	15.2	41.2	81.0
*C2phenanthrenes/anthracenes***	17.9	543	245
*C3phenanthrenes/anthracenes***	27.3	48.0	129
*C4phenanthrenes/anthracenes***	6.50	15.2	24.5
*Retene***	29.2	590	355
*C5phenanthrenes/anthracenes***	13.3	20.5	78.7
∑ Phenanthrenes/Anthracenes	112	1262	933
Fluoranthenes/pyrenes	3.78	11.8	37.9
*C1-fluoranthenes/pyrenes***	3.23	12.4	39.7
*C2- fluoranthenes/pyrenes **	9.02	12.1	45.8
*C3- fluoranthenes/pyrenes **	9.00	10.8	23.3
*C4- fluoranthenes/pyrenes **	7.43	5.9	10.7
*C5- fluoranthenes/pyrenes **	nd	0.97	4.8
∑ Fluoranthenes/pyrenes	32.5	53.9	162
∑Alkyl Homologues**	**155**	**1405**	**1656**

a: Values are not adjusted by total organic carbon content. Total organic carbon (TOC) is 0.55% at Site A and 2.2% at Site B and Site C. After adjusting TOC, means of ∑parent PAHs are 11.4 μg/g at Site A, 6.6 μg/g at Site B and 14.5 μg/g at Site C, and means of ∑alkyl homologues PAHs are 28.2 μg/g at Site A, 63.9 μg/g at Site B and 75.2 μg/g at Site C.

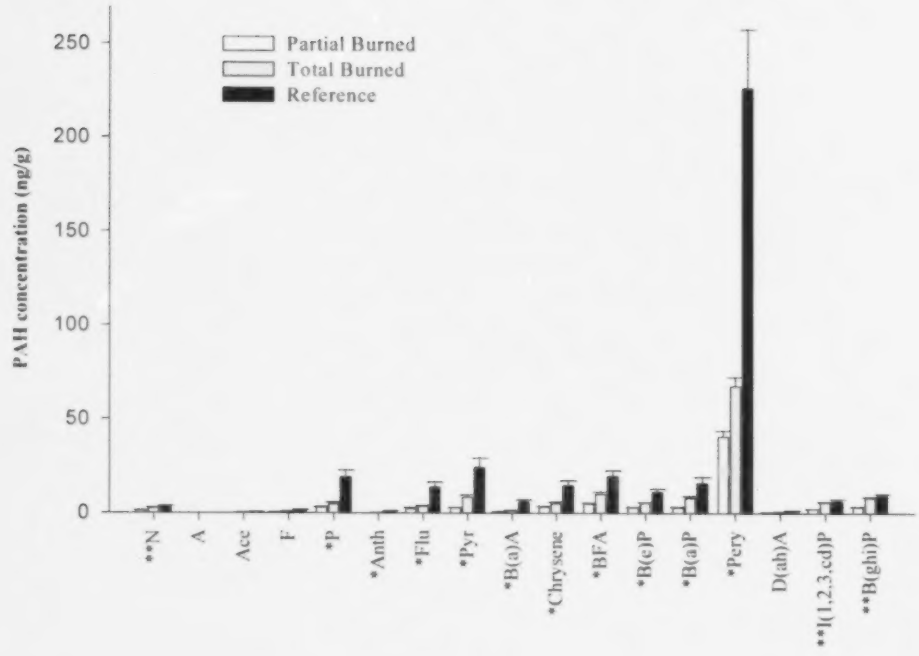

Figure 6-1 Mean Concentrations (dry weight) of Parent PAHs in Sediment

* levels at reference site > partially and totally burned sites, $p<0.01$. ** levels at partially burned site > totally burned and reference sites, $p<0.01$). [N= Naphthalene, A= Acenaphthylene, Ace= Acenaphthene, F= Fluorene, P= Phenanthrene, Anth= Anthracene, Flu= Fluoranthene, Pyr= Pyrene, B(a)A= Benzo[a]anthracene, BFA= Benzofluoranthenes, B(e)P= Benzo[e]pyrene, B(a)P= Benzo[a]pyrene, Pery= Perylene, D(ah)A= Dibenzo[ah]anthracene, I(1,2,3,cd)P= Indeno[1,2,3,cd]pyrene, and B(ghi)P= Benzo[ghi]perylene]

Concentrations of alkylated naphthalene derivatives except for 2,3,6-trimethynaphthalene were significantly higher at the reference site than the burned sites. C2 and C3 naphthalenes prevailed at all sites (Figure 6-4). PCA analysis revealed that C2, C3, 2,3,5-trimethyl-, C4, C5 and cadalene (1,6-dimethly-4-isopropylnaphthalene) were associated with the reference site.

Concentrations of alkylated fluoanthenes/pyrenes (F/P) derivatives except for C4 F/P were significantly higher at the reference site than the burned sites. The proportions of C1 to C5 F/P in the total alkyl F/P except for C1 F/P at the partial burned were similar at the three sites (Figure 6-5). PCA indicated that parent perylene and C1 and C2 F/P were associated with the reference site.

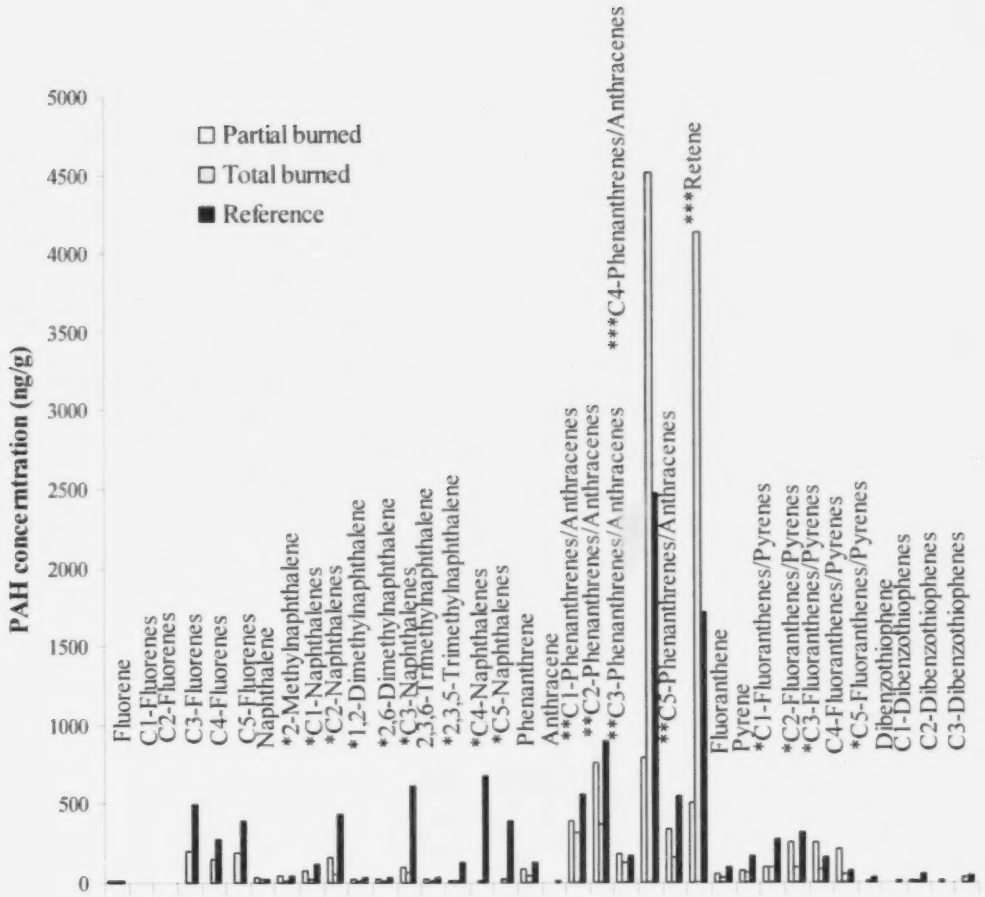

Figure 6-2 Distribution Patterns of PAH Homologous Groups

* is levels were higher at the reference site than the two burned sites, $p < 0.01$; ** is levels were higher at the reference site than the two burned sites, $p < 0.05$; *** is levels were higher at the totally burned site than partially burned and reference sites, $p < 0.05$.

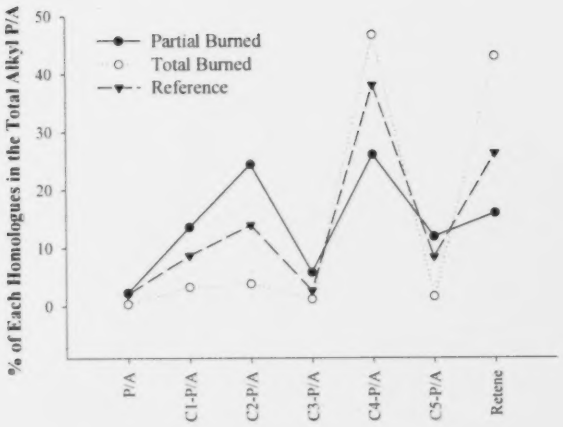

Figure 6-3 Distribution Patterns of Alkyl Phenanthrene/Anthracene (P/A) Series

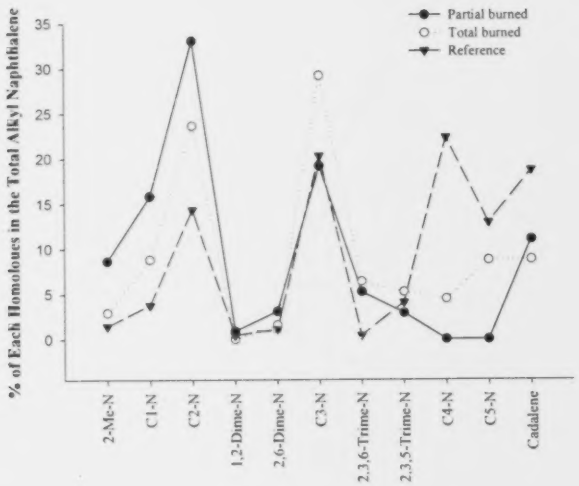

Figure 6-4 Distribution Patterns of Alkyl Naphthalene (N) Series

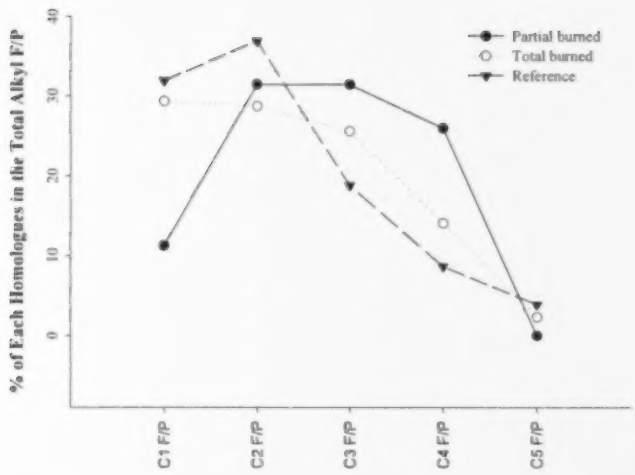

Figure 6-5 Distribution Patterns of Alkyl Fluoranthene/Pyrene (F/P) Series

In non-routine PAH analysis, the predominating compounds were dehydroabietin (410 ng/g) and tetrahydroretene (1400 ng/g) at the totally burned site, and simonellite (160 ng/g) and 2,2,9-tetrahydropicene (120 ng/g) at the reference site. Concentrations of 3,3,7-methyltetrahydrochrysene were relatively high at the totally burned site (54 ng/g) and reference site (41 ng/g). Sulphur compounds such as 2-methyl and 2,4-dimethyl dibenzothiophenes, benzo[b]naphtho[1,2-d]thiophene, benzo[b]naphtho[2,3-d]thiophene were the least abundant.

Benzofluoranthenes, indeno[1,2,3,cd]pyrene, and benzo[ghi]perylene are pyrolytic origins associated with soot particles (Dachs et al. 1997). Pyrolytic origins are associated with long-range transportation by atmosphere. Fluoranthenes/pyrenes are the major contributors from anthropogenic combustion sources (Sporstøl et al. 1983). A predominance of the parent PAH derivatives over alkyl PAHs may indicate a major contribution from anthropogenic combustion sources (Yunker et al. 1993; Yunker et al. 1996). A predominance of the alkyl PAH derivatives over parent PAHs and low concentrations of fluoranthene, pyrene, benzofluoranthenes, indeno[1,2,3,cd]pyrene, and benzo[ghi]perylene observed in this study suggested that there was an insignificant input of PAHs from long-range atmospheric transportation of pyrogenic particulate and anthropogenic combustion products.

Naphthalenes are sensitive as a petroleum indicator and are removed more quickly in sediment (Sporstøl et al. 1983). Phenanthrene is presumably of fossil origin resulting from point pollution sources. Dibenzothiophenes and chrysene are common constituents of uncombusted fossil fuel (Sporstøl et al. 1983; Dachs et al. 1997). Sulphur compounds originate from petroleum, coal combustion and other pyrolytic processes (Berthou and Vignier 1986). The low proportions and

concentrations of these compounds observed at the three sites reflect a minor contribution from pyrolytic relics to the study area.

Perylene is the most prevailing constituent in the three sites, and this is consistent with other studies (Wakeham et al. 1977; Venkatesan 1988; Yunker et al. 1993). Perylene is a naturally-derived origin in sediment, forming by a diagenic process (e.g. bacterial degradation) (Wakeham et al. 1980; Tolosa et al. 1996). The abundance of perylene may indicate that in situ generation of perylene by transformation of some terrestrially-derived precursors occurred at these sites.

The presence of retene and P/A homologues in the environmental media may reflect both petrogenic and terrigenous sources. Retene is a short-term diagenic product of abietic acid and is abundant in the resins of conifers and other high plant lipids (LaFamme and Hites 1978; Shaw et al. 1979; Wakeham et al. 1980). Retene is often considered as a unique marker for coniferous wood combustion (e.g. forest fires) (Ramdahl 1983). Elevated concentrations of retene in the air were observed following forest fires in the Canadian Arctic (NCP 1997). Cadalene, alkylated naphthalene homologous, and some retene-related precursors such as simonellite, dehydroabietin, tetrahydroretene are also prime constituents of diagenic origins (higher plant alteration) (Shaw et al. 1979; Wakeham et al. 1980; Lipiatou and Saliot 1991).

Coniferous forest dominates in northern Alberta. A significant enrichment of terrestrial origin compounds observed at all sites indicates the major contribution of PAHs in the study area resulting from terrestrial plants and diagenic process. The high concentration and proportion of retene observed at the totally burned area suggests that forest fires contributed to naturally-derived PAHs in the study area.

PCDD/Fs and PCBs

The total PCDD/F concentrations were 1.82 pg/g at the partially burned site, 4.98 pg/g at the totally burned site and 4.88 pg/g at the reference site. After normalizing to total organic carbon, the levels were 300, 226 and 221 pg/g, respectively. 1,2,3,6,7,8-hexa-CDD, 1,2,3,4,6,7,8-hepta-CDD, OCDD, 1,2,3,4,6,7,8-hepta-CDF and OCDF were detected. The mean concentrations and profiles of PCDD/Fs were not significantly different across the sites. The relative abundance of these congeners was similar in all sites examined (Figure 6-6) with OCDD being the most prevalent component.

PCDD/Fs were detected in the air, soil and ash samples resulting from controlled forest fires (Tashiro et al. 1990). Relatively higher concentrations of tetra, penta, hexa- and hepta-CDDs were observed in the air sample after the test burn. O8CDD, P5CDD and H7CDD were found in the soil samples after the test burn, (ranging from 46 to 270 pg/g). Concentrations of PCDD/Fs reported in this study were very low and consistent with typical atmospheric deposition (i.e. 1 ng/g) reported from other studies (Eitzer 1993; Rose et al. 1994; Bonn 1998). The low levels of PCDD/Fs and the similarities among profiles of PCDD/Fs from all the sites suggest that the contributing source is atmospheric deposition rather than an influence of forest fires.

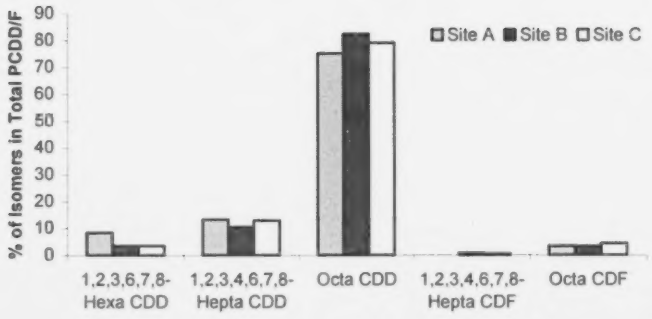

Figure 6-6 Distribution Patterns of PCDD/Fs in Sediment Samples

The sediment samples were examined for all 209 PCB congeners. The overall total PCBs concentrations in the three sites examined were similar, 258, 283 and 247pg/g, dry weight, respectively for sites A, B and C. Concentrations of measured congeners and percentages of each measured congener in the total 209 congeners are presented in Table 6-2. The non-ortho PCB group was less abundant, accounting for 5% to 8% of the total 209 congener content. The predominant congeners in this group were CB-11, CB-15 and CB-37, with the concentrations ranging from 4 to 7 ng/g, dry weight. Compared to the sample means, the level of CB-38 at the totally burned site was significantly higher than at other two sites. The mono-ortho PCBs accounted for 27% to 32% of the total PCBs. The major contributors were CB-8, CB-28, CB-31, CB-33 and CB-118, with the concentrations ranging from 4.5 to 17 ng/g. CB-28 was the most abundant congener (6% of the total PCBs) at the totally burned site. The di-ortho PCB accounted for 60% to 65% of the total PCBs. Higher concentrations were observed for CB-138, CB-153, CB-149, CB-101, CB-52 and CB-64 in the di-ortho group, ranging from 7 to 11 ng/g. Each predominating congener accounted for 3% to 4.5% of the total PCBs.

There is little information about natural sources of PCBs. One study found some PCB congeners that would not originate from commercial PCB products (Pereira et al. 1980). CB-138, CB-153, CB-149 and CB-101 are typically detected in the sediment samples (Durell and Lizotte 1998). In general, the measured 209 congener levels in the study areas are considered to be indicative of background levels. The similarities of PCB profiles at all the locations suggested a common source. Concentrations of CB-28 and CB-38 were significantly higher at the totally burned site than the reference site. Whether CB-28 and CB-38 concentrations were influenced by forest fires needs to be investigated in the future.

Table 6-2 Means of PCB Congeners in Sediment Sample (pg/g, dry weight)

PCB No.	Partial Burned (%)	Total burned (%)	Reference (%)
	Non-ortho		
11	3.28 (1.27)	2.78 (0.98)	4.17 (1.69)
12	<0.20	<0.20	<0.20
13	1.38 (0.53)	1.34 (0.47)	1.46 (0.59)
14	<0.20	0.07 (0.03)	0.04 (0.02)
15	4.02 (1.56)	4.53 (1.60)	7.48 (3.03)
35	0.21 (0.08)	0.26 (0.09)	0.29 (0.12)
36	<0.04	<0.04	<0.04
37	2.95 (1.15)	4.09 (1.45)	4.17 (1.69)
38	0.49 (0.19)	1.42[a] (0.50)	0.24 (0.10)
39	<0.04	<0.04	<0.04
78	<0.04	<0.04	<0.04
79	<0.04	<0.04	<0.04
80	0.52 (0.20)	0.50 (0.18)	0.83 (0.34)
81	<0.04	<0.04	<0.04
127	0.14 (0.05)	0.11 (0.04)	0.26[b] (0.11)
77	0.46 (0.18)	0.11 (0.19)	0.26 (0.19)
126	0.01 (0.00)	0.03 (0.01)	0.06 (0.02)
169	0.08 (0.03)	0.12 (0.04)	0.10 (0.04)
Σ	**13.6 (5.25)**	**15.8 (5.58)**	**19.3 (7.93)**
	Mono-ortho		
6	2.90 (1.13)	2.35 (0.83)	2.78 (1.13)
7*	1.82 (0.71)	1.08 (0.38)	2.34 (0.95)
8*	11.49 (4.46)	11.50 (4.06)	7.38 (2.99)
21	<0.1	<0.1	<0.1
22	3.78 (1.47)	4.49 (1.58)	2.74 (1.11)
23	<0.1	<0.1	<0.1
25	0.74 (0.29)	0.87 (0.31)	0.55 (0.22)
26	1.35 (0.52)	1.98 (0.31)	0.86 (0.22)
28	14.81 (5.75)	17.36[a] (6.13)	8.94 (3.62)
29	<0.1	<0.1	<0.1
31	10.00 (3.88)	11.92 (4.21)	6.40 (2.59)
33*	7.00 (2.72)	7.59 (2.68)	4.57 (1.85)
34	<0.1	<0.1	<0.1
55	0.02 (0.01)	0.05 (0.02)	0.11 (0.04)
56*	3.77 (1.46)	4.14 (1.46)	3.47 (1.40)
57	<0.1	<0.1	<0.1
58	<0.1	<0.1	<0.1
63	0.11 (0.04)	0.14 (0.05	0.18 (0.07)
66	4.72 (1.83)	5.18 (1.83)	4.63 (1.87)
67	0.22[c] (0.09)	0.20 (0.07)	0.09 (0.04)
68	<0.1	<0.1	<0.1
70	5.48 (2.13)	6.50 (2.30)	5.51 (2.23)
72	<0.1	0.05 (0.02)	<0.1
74*	3.26 (1.26)	3.23 (1.14)	3.47 (1.41)
105	1.91 (0.74)	2.87 (1.01)	2.75 (1.11)
108*	0.26 (0.10)	0.42 (0.15)	0.42 (0.17)
111	<0.1	<0.1	<0.1
114	0.16 (0.06)	0.18 (0.06)	0.22 (0.09)
118	4.49 (1.74)	6.81 (2.41)	6.22 (2.52)
120	<0.1	<0.1	<0.1
122	<0.1	<0.1	0.03 (0.01)
123	<0.1	<0.1	0.29 (0.12)
124	0.16 (0.06)	0.26 (0.09)	0.24 (0.10)
156	0.54 (0.21)	0.71 (0.25)	0.81 (0.48)
157	0.75 (0.29)	0.83 (0.29)	0.84 (0.34)
159	<0.1	<0.1	0.02 (0.01)
162	<0.1	<0.10	0.05 (0.02)
167	0.10 (0.04)	0.30 (0.11)	0.29 (0.12)
189	0.04 (0.02)	<0.1	0.07 (0.03)
Σ	**80 (31.00)**	**91 (32.15)**	**66 (26.83)**
	Di-ortho		
4*	1.58 (0.61)	1.41 (0.50)	0.94 (0.38)
17	2.99 (1.16)	2.44 (0.86)	1.86 (0.75)
18	6.94 (2.69)	5.66 (2.00)	4.82 (1.95)
19*	0.67 (0.26)	0.50 (0.18)	0.35 (0.14)
27*	0.37 (0.14)	0.45 (0.16)	0.24 (0.10)
30	<0.1	<0.10	0.30 (0.12)
32*	5.20 (2.02)	4.07 (1.44)	3.65 (1.48)
40	0.80 (0.31)	0.84 (0.30)	0.93 (0.38)
42*	2.94 (1.14)	3.03 (1.07)	2.58 (1.05)
43	<0.1	<0.1	<0.1
44	6.44 (2.50)	6.94 (2.45)	5.57 (2.25)
45	1.37 (0.53)	1.19 (0.42)	1.17 (0.48)
46	0.65 (0.25)	0.53 (0.19)	0.52 (0.21)
47*	3.84 (1.49)	3.81 (1.35)	3.25 (1.32)
49	5.09 (1.97)	5.45 (1.35)	4.55 (1.84)
50	<0.1	<0.1	<0.1
51	0.47 (0.18)	0.42 (0.15)	0.41 (0.17)
52*	9.38 (3.64)	10.92 (3.86)	8.33 (3.37)
53	1.18 (0.46)	1.04 (0.37)	0.92 (0.37)
54	<0.1	<0.1	<0.1
62	<0.1	<0.1	<0.1
64*	7.79 (3.02)	8.73 (3.08)	8.36 (3.39)
65	<0.1	<0.1	<0.1
69	<0.1	<0.1	<0.1
82	0.53 (0.21)	0.92 (0.33)	0.49 (0.20)
84*	0.97 (0.38)	1.62[d] (0.57)	0.98 (0.40)
85	0.90 (0.35)	1.38 (0.49)	0.79 (0.32
86	1.07 (0.41)	2.42 (0.86)	0.98 (0.50)
87*	2.66 (1.03)	4.24 (1.50)	2.54 (1.03)
88*	<0.1	<0.1	<0.1
89	1.40 (0.54)	2.17 (0.77)	1.23 (0.50)
91	0.65 (0.25)	1.02 (0.36)	0.63 (0.25)

(Continued)

PCB No.	Partial Burned (%)	Total burned (%)	Reference (%)	PCB No.	Partial Burned (%)	Total burned (%)	Reference (%)
Di-ortho				155	<0.1	<0.1	<0.1
94	<0.1	<0.1	<0.1	158	0.62 (0.24)	0.89 (0.31)	0.71 (0.29)
95	4.59 (1.78)	7.97[e] (2.82)	5.08 (2.06)	165	<0.1	<0.1	<0.1
96	<0.1	<0.1	<0.1	166	<0.1	0.03 (0.01)	<0.1
98	<0.1	<0.1	<0.1	168	1.82 (0.71)	2.29 (0.81)	2.38 (0.97)
99	2.16 (0.84)	3.69 (1.30)	2.13 (0.86)	170*	1.30 (0.50)	1.62 (0.57)	1.86 (0.75)
100	<0.1	<0.1	<0.1	171	0.46 (0.18)	0.61 (0.22)	0.63 (0.26)
101	6.98 (2.71)	9.96 (3.52)	7.14 (2.89)	173	<0.1	<0.1	<0.1
102*	0.14 (0.05)	0.27 (0.10)	0.13 (0.05)	175	0.09 (0.03)	<0.1	0.08 (0.03)
103	<0.1	<0.1	<0.1	176	0.66 (0.26)	0.69 (0.24)	0.87 (0.35)
104	<0.1	<0.1	<0.1	177	1.25 (0.49)	1.45 (0.51)	1.55 (0.63)
109*	0.17 (0.07)	0.39[d] (0.14)	0.22 (0.09)	178	0.57 (0.22)	0.68 (0.24)	0.77 (0.31)
110	4.38 (1.70)	7.72[d] (2.73)	4.81 (1.95)	179	1.80 (0.70)	1.89 (0.67)	2.35 (0.95)
112	<0.1	<0.1	<0.1	180	3.40 (1.32)	3.80 (1.34)	4.45 (1.80)
113	<0.1	<0.1	<0.1	181*	2.49 (0.96)	2.90 (1.02)	3.30 (1.34)
116*	<0.1	<0.1	<0.1	183	1.40 (0.54)	1.60 (0.57)	1.84 (0.75)
119	0.04 (0.02)	0.19 (0.07)	0.11 (0.04)	184	<0.1	<0.1	<0.1
121	<0.1	<0.1	<0.1	185	0.39 (0.15)	0.44 (0.15)	0.54 (0.22)
128	0.77 (0.30)	1.21[d] (0.43)	0.86 (0.35)	186	<0.1	<0.1	<0.1
129	0.02 (0.01)	0.23[d] (0.08)	0.12 (0.05)	187*	3.08 (1.20)	3.68 (1.30)	3.66 (1.48)
130	0.59 (0.23)	0.92 (0.33)	0.60 (0.24)	188	<0.1	<0.1	<0.1
133	<0.1	<0.1	<0.1	191	0.02 (0.01)	<0.1	<0.1
135*	1.64 (0.64)	1.77 (0.62)	2.07 (0.84)	192	0.17 (0.07)	0.30 (0.10)	0.27 (0.11)
136	1.83 (0.71)	1.68 (0.59)	2.33 (0.94)	193	0.15 (0.06)	0.14 (0.05)	0.23 (0.09)
137	0.21 (0.08)	0.41 (0.14)	0.22 (0.09)	194	0.97 (0.38)	1.02 (0.36)	1.14 (0.46)
138*	7.15 (2.77)	9.54 (3.37)	8.88 (3.6)	195	0.28 (0.11)	0.32 (0.11)	0.36 (0.14)
139	<0.1	<0.1	<0.1	197	<0.1	<0.1	<0.1
141	1.77 (0.69)	2.25 (0.80)	2.33 (0.94)	198	<0.1	<0.1	<0.1
142*	<0.1	0.06 (0.02)	0.05 (0.02)	199	0.14 (0.05)	0.09 (0.03)	0.39[b] (0.16)
143*	0.10 (0.04)	0.26 (0.09)	0.28 (0.11)	200	0.40 (0.15)	0.35 (0.12)	0.72 (0.29)
145	<0.1	<0.1	<0.1	201	0.80 (0.31)	0.97 (0.34)	1.02 (0.41)
146*	1.08 (0.42)	1.37 (0.48)	1.28 (0.52)	202	0.58 (0.23)	0.57 (0.20)	0.83 (0.34)
147	0.02 (0.01)	0.06 (0.02)	0.02 (0.01)	203*	1.38 (0.53)	1.43 (0.51)	1.76 (0.71)
148	<0.1	<0.1	<0.1	204	<0.1	<0.1	<0.1
149	8.59 (3.33)	8.77 (3.10)	10.99(4.45)	205	<0.1	<0.1	<0.1
150	<0.1	<0.1	<0.1	206	0.75 (0.29)	0.30 (0.11)	0.87 (0.35)
151	3.12 (1.21)	2.96 (1.05)	3.94 (1.60)	207	0.28 (0.11)	<0.1	0.24 (0.10)
152	<0.1	<0.1	<0.1	208	0.28 (0.11)	0.07 (0.02)	0.31 (0.13)
153*	8.96 (3.48)	10.57 (3.74)	9.74 (3.94)	209	18.59 (7.21)	4.69 (1.66)	8.02 (3.25)
154	<0.1	0.03 (0.01)	<0.1	Σ	**164 (62.75)**	**176 (62.27)**	**161 (65.24)**

Note: PCB No. = IUPAC numbers. Co-elute: 7*=7/9, 8*=8/5, 33*=33/20, 56*=56/60, 74*=74/61, 108*=108/107, 4*=4/10, 19*=19/30, 27*=27/24, 32*=32/16, 42*=42/59, 47*=47/75/48, 52*=52/73, 64*=64/41/71, 84*=84/92, 87*=87/115, 88*=88/97, 102*=102/93, 109*=109/83, 116*=116/125, 135*=135/144, 138*=138/160/163/164, 142*=142/131, 146*=146/161, 153*=153/132, 170*=170/190, 181*=181/174, 187*=187/182, 203*=203/196.

a: difference between totally burned and reference sites ($p < 0.05$)

b: difference between reference and totally/partially burned sites ($p < 0.05$)

c: difference between partially burned and reference sites ($p < 0.05$)

d: difference between totally burned and partially burned sites ($p < 0.05$)

e: difference between totally burned and partially burned/reference sites ($p < 0.05$)

6.2 Mercury in Fish

Mercury is an element that occurs naturally in the environment in several forms. The most common mercury forms are metallic mercury and methylmercury found in the environment. The form of mercury can be changed through microorganisms and natural processes. Metallic mercury vapor may be released to the air by forest fire events and deposited to the water. Methylmercury can be formed in the bottom of the lake by natural processes. Mercury can also be emitted from fossil fuel combustion and waste incineration (Louchouarn et al. 1993; USEPA 1996).

Mercury is a concern in aquatic ecosystems due to its bioaccumulation and its developmental toxicity to humans, especially young children. There is existing mercury-related fish consumption advisory on brook trout in Chrystina Lake issued in the early 1990s. In order to review the fish consumption advisory, a project investigating mercury levels in brook trout was carried out between 1999 and 2001.

6.2.1 Materials and Methods

6.2.1.1 Field Collection

The field collection was carried out by the researchers in the Department of Biologic Sciences at University of Alberta between August and September 1999, and August 2001. Brook trout and white sucker were collected by gill nets in Chrystina Lake. Whole fish were wrapped in aluminum foil, placed in plastic bags and transported on ice to the laboratory at the Department of Biological Sciences for storage and analysis. Scales and fins were removed to control for aging. Length, weight and sex were measured and recorded. All fish samples were kept at –20 ^{o}C prior to mercury analysis.

Sixteen brook trout, with average total length of 272 mm and weight of 201 grams, and fifteen white sucker, with average total length of 291 mm and weight of 280 grams, were collected in 1999. Sixteen brook trout, with average total length of 306 mm and weight of 341 grams, and fifteen white sucker, with average total length of 287 mm and weight of 263 grams, were collected in 2001.

6.2.1.2 Sampling Processing and Mercury Analysis

All brook trout and white suckers collected in 1999 were sent to the National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ontario for total mercury (T-Hg) analysis. Six brook trout and six white sucker were sent to Flett Research Ltd. in Winnipeg for methyl mercury (MeHg) analysis. All brook trout and white sucker collected in 2001 were sent to Flett Research Ltd. for total mercury analysis.

The fish specimens were homogenized and analysed for both methyl mercury and total Hg (T-Hg). Those analyzed for MeHg were processed according to the method given in Horvat et al.

(1997). MeHg from approximately 0.2 g of homogenized sample was released from the sample by saponification with 1.5 ml of 25% KOH in methanol at 70 °C overnight. When cooled, the saponified sample was diluted to 28.8 ml with methanol. An aliquot (max. 15 µl) was subjected to derivatization with sodium teraethylborate at pH 4.9 and the ethylated Hg species were then collected at room temperature on a Tenax trap and subsequently swept on a GC column (5 ft. X 1/4 in 15 % OV3 on 60-80 Chromosorb WAWDMCS), pyrolysis unit and CVAFS detector. Modifications to this methodology included increasing the size of the samples to 1.0 g.

Samples for total Hg analysis were performed for fillet and whole fish. Fillets were removed and weighed before homogenizing. Five grams of fillets were used for T-Hg analysis. The remainder of the fish (whole fish) was weighed and homogenized. Ten grams of whole fish tissues were used for T-Hg analysis.

About 0.2-0.5 grams of the homogenates were digested with 5 mL sub-boiled, distilled concentrated nitric acid and 0.5 mL concentrated HCl (Seastar) in closed PFA Teflon vessels. A pressurized microwave oven was employed (modified EPA Method 5051). The cooled digests were filtered (0.4 µ polycarbonate membrane) and diluted with BrCl in water. The solutions were analyzed by cold vapour atomic spectroscopy. Detection limit was 2 pg/mL.

6.2.2 Results and Discussions

Mean concentrations of total mercury in fillets of brook trout and white sucker are summarized in Table 6-3. Total mercury concentrations were similar in brook trout and white suckers from Chrystina Lake in 1999 and 2001. The average concentrations of mercury in fish from Christina Lake fall within the average concentrations of mercury in most fish in North America (less than 200 µg/kg) (ATSDR 1994). Mercury concentrations were found to increase with both age and length of fish. This pattern is consistent with those reported in the literature. The older and larger fish contain higher concentrations of mercury.

Mean concentrations of methyl mercury (MeHg) in select fillets are listed in Table 6-4. MeHg was measured in the largest fish from Christina Lake. Ratios of methylmercury to total mercury were 1.28 in brook trout and 1.09 in white suckers. These higher ratios were likely the result of the use of two different laboratories for methyl mercury and total mercury analysis. These results indicate that methyl mercury is major specie in fish muscle tissue. Methylmercury constitutes over 99% of the total mercury detected in fish muscle (Grieb et al. 1990; Bloom 1992).

Mercury is a naturally occurring element found in rocks, soils, water and air. Mercury can also enter the environment from human activities. Fish absorb methylmercury from water through uptake processes of gills or through the consumption of prey. Almost all of the mercury in fish is in the form of methylmercury. Mercury is tightly bound to proteins in all fish tissue. The older and larger fish contain more mercury.

Table 6-3 Means of Total Mercury in Fish Fillets from Chrystina Lake (μg/kg, wet weight)

Sample No.	Brook Trout		White Sucker	
	1999	**2001**	**1999**	**2001**
Sample 1	129.15	148	384.85	103
Sample 2	136.98	150	134.41	105
Sample 3	158.84	152	254.21	131
Sample 4	129.31	157	130.79	143
Sample 5	139.67	163	135.71	143
Sample 6	131.20	165	193.57	152
Sample 7	170.37	173	139.91	164
Sample 8	101.93	174	84.79	167
Sample 9	125.73	179	197.18	198
Sample 10	115.61	185	146.71	205
Sample 11	102.44	198	166.89	217
Sample 12	71.79	200	388.94	218
Sample 13	77.63	202	162.26	235
Sample 14	70.25	249	247.06	250
Sample 15	78.56	459	210.80	391
Sample 16	125.06	-	99.92	-
Average	**122**	**197**	**188**	**188**

Table 6-4 Means of Methyl Mercury in Fish Fillets in 1999 (μg/kg, wet weight)

Sample No.	Brook Trout		White Sucker	
Sample 1, 2	196	132	320	195
Sample 3, 4	138	97	144	389
Sample 5,6	132	110	196	157
Average		**134**		**233**

Small amounts of ingested methylmercury are eliminated from the body with no adverse effects. Larger amounts may damage the nervous system. Methylmercury builds up in the human body over time. The fetus is more sensitive to mercury. Health Canada has proposed the guidelines and a total daily intake for the consumption of mercury-contained fish. In the absence of intake estimations, the guideline is 500 μg/kg (0.5 ppm) Hg for commercial fish. This guideline is used as a general screening tool. The guideline for subsistence fresh water fishing populations is 200 μg/kg (0.2 ppm) Hg. The concentrations of total mercury in brook trout and white sucker from Chrystina Lake were less than 200 μg/kg.

Health Canada proposed that the total daily intake (TDI) of mercury is 0.2 μg Hg/Kg bw/d for women of childbearing age and children, and 0.47 μg Hg/Kg bw/d for the general population. Estimated daily intake and exposure ratios based on TDIs from Health Canada are summarized in Table-6-5.

Table 6-5 Estimated Daily Intake (EDI) and Exposure Ratio (ER)

Consumption Group			High Intake (>100 g/d)		Medium Intake (30-99 g/d)		Low Intake (3-29 g/d)		Very Low Intake (<4 g/d)	
Concentration (μg/kg)*			122	197	122	197	122	197	122	197
Brook Trout	EDI**	T-Hg (μg/kg/d)	0.28	0.45	0.08	0.13	0.02	0.04	0.003	0.005
	ER	TDI (0.2 μg/kg/d)	**1.40**	**2.25**	0.39	0.63	0.11	0.18	0.017	0.027
	ER	TDI (0.47 μg/kg/d)	0.59	0.96	0.17	0.27	0.05	0.08	0.007	0.011

* Mean concentrations: 122 μg/kg, wet weight, in brook trout from Chrystina Lake in 1999; 197 μg/kg, wet weight, in brook trout from Chrystina Lake in 2001. ** Ingestion rates: high intake group = 0.167 kg/d, medium intake group = 0.047 kg/d, low intake group = 0.013 kg/d, and very low intake group = 0.002 kg/d. Body weight = 73 kg.

Exposure ratios were greater than one for the high intake group of women of childbearing age and children. Hence, women of childbearing age and children should not consume a large quantity of brook trout caught from Chrystina Lake.

6.2.3. Summary

The average concentrations of total mercury in brook trout from Chrystina Lake were less than 200 μg/kg in 1999 and 2001. Exposure ratios were greater than one for the high intake group of women of childbearing age and children. Hence, women of childbearing age and children should not consume a large quantity of brook trout caught from Chrystina Lake.

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7. Summary

Concentrations of PCBs and PCDD/Fs in blood were similar in residents living in the Swan Hills area in 1997 and 2001 surveys. TEQ values of PCDD/Fs in the 2001 survey are higher than those in the previous survey. The higher TEQ values were attributed to 1,2,3,6,7,8-HxCDD and 1,2,3,7,8-PeCDD.

The levels of ΣPCBs TEQ increased in the liver of deer in 2001 as compared to those in the 1997 and 1999 studies. Overall levels of ΣPCBs TEQ in the muscle of deer in 2001and 1999 declined as compared to the 1997 levels. Overall levels of ΣPCDDs/Fs in the liver of deer declined in 2001 as compared to the 1997 levels but increased as compared to 1999 levels. The ΣPCDDs/Fs levels in muscle in 1999 and 2001 increased as compared to 1997 levels. The levels of ΣPCDDs/Fs TEQ increased in the liver and muscle in 2001 as compared to those in the 1997 and 1999 studies.

Distribution patterns of ∑PCDD/Fs, ∑PCBs and ∑TEQ in deer in the 1998/99 and 2000/01 studies were consistent with those observed in the 1997 study and the annual monitoring programs conducted by the company. The inverse relationship between concentrations and distance to the facility suggests that the contamination is limited to the immediate vicinity of the facility.

The mean concentrations of ∑PCDDs/Fs, ∑PCBs and ∑TEQ in the muscle and liver samples in brook trout from Chrystina Lake in 2000 were significantly declined as compared to those in 1997.

Exposure ratios related to ∑PCDDs/Fs and ∑PCBs were less than one for consuming muscle tissues of wild games and brook trout. The exposure ratios for the group of consuming liver tissues in wild game based on the 2001 study for consumption two grams liver per day were four fold higher than the value proposed from Health Canada TDI for TCDD. Therefore, there is a need to continue wild game monitoring prior to conducting a review of current food consumption advisories.

The average concentrations of total mercury in brook trout from Chrystina Lake were less than 200 μg/kg in 1999 and 2001. Exposure ratios related to mercury were greater than one for the high intake group of women of childbearing age and children. Hence, women of childbearing age and children should not consume a large quantity of brook trout caught from Chrystina Lake.

8. Recommendations

The current food consumption advisories for PCDD/Fs and PCBs should continue. Women of childbearing age and children should not consume a large quantity of brook trout caught from Chrystina Lake.

The long-term human health and environmental monitoring program should continue. This should include wild game monitoring, fish monitoring and human blood monitoring. Review of the food consumption advisories should be ongoing.

Appendices

Appendix A

Public News Release (December 1996)

Alberta
HEALTH

News Release

Edmonton, December 13, 1996

Public Health Advisory

Alberta's Provincial Health Officer, Dr. John Waters, today issued a public health notice advising against eating wild game taken from the Swan Hills area.

The advisory is based on preliminary test results received by Alberta Health from Alberta Environmental Protection regarding initial animal tissue samples collected in the Swan Hills area. This information indicates **no immediate threat to human health**. However, the studies are not yet complete and more information is required before a final determination can be made.

The tissue samples were collected as a result of an air emissions release containing Poly Chlorinated Biphenyls (PCBs), dioxins and furans which occurred at the Swan Hills Treatment Centre on October 16, 1996.

"When dealing with issues that may even remotely affect public health it is best to err on the side of caution, said Dr. Waters. "I am therefore advising that precautionary measures be taken to minimize potential health risks that may be associated with eating wild game from the area.

Alberta Health is currently conducting a comprehensive health risk assessment. The public will be provided with any information which may alter the Public Health Advisory. An initial report will be issued in approximately two months containing findings of the health risk assessment which will be ongoing for several months.

Until these results are released and the advisory revoked, the following precautionary measures are recommended:

- Avoid eating wild game taken from a 30 km radius of the Swan Hills Treatment Centre. This 30 km radius includes a safety factor of approximately 10 times that of the potential range of game in the area.
- If wild game from the area has already been eaten, simply avoid eating any more of the meat. Again no health risk has been identified and the consumption of potentially contaminated meat would have to occur over a number of years before it could lead to any adverse health effects.

- There is no need to dispose of any wild meat until further information is available. Meat should be stored in the freezer with clearly marked labels until Alberta Health is able to assess and advise on any possible health risks.

"We have no information to date to indicate that there is any public health risk or a risk to individuals who may have previously eaten meat from the area. However, the role of Alberta Health and the Provincial Health Officer is to be extremely cautious and ensure that, above all, public health is protected," concluded Dr. Waters.

If the public would like more information on this health advisory they may dial 1-800-883-5551 between the hours of 8:15 a.m. and 4:30 p.m. Monday to Friday. For more information, contact:

Dr. John Waters
Provincial Health Officer
(403) 422-4711

Garth Norris
Alberta Health Communications
(403) 427-7164

Alberta
HEALTH

Background

Edmonton, December 13, 1996

Who is affected by the advisory?

The advisory only applies to people who eat wild game taken from within a 30 km radius of the Swan Hills Centre. Only animals near the Swan Hills Treatment Centre would potentially be affected by the emission.

How far reaching are the effects of the release?

Toxicology experts indicate that the emission reached the ground within a three kilometre radius of the plant site and that there is no direct threat to the surrounding population, including the town of Swan Hills. To ensure all precautions are taken to minimize potential public health risks, the game advisory has been extended to include the areas within a 30 kilometre radius of the plant site.

What are the health effects?

There is no reason to expect negative health effects from consuming the wild game even if significant levels of toxins are found in the meat. Health effects such as chloracne (an acne like skin condition), skin discolouration, headaches, swelling around the eyes, weakness, numbness, weight loss, or abnormal liver functioning may sometimes occur. These are seen only if a high level of exposure occurs over a number of years.

If I have already eaten wild meat from the area what should I do? Should I see a doctor?

The only thing you need to do is to stop consuming the meat. You do not need to see a doctor. Again, health is affected only following long-term exposure to high levels of PCBs, dioxins and furans.

If there are no negative health effects, why can=t I eat the meat?

There are unlikely to be health effects, however, until we conduct further tests it is best to avoid eating the meat. Alberta Health wants to minimize exposure to any level of PCBs, dioxins and furans.

What will a health risk assessment determine?

The health risk assessment will determine, where possible, the amount of contaminants to which the people and the environment were exposed. This will likely involve further testing of animals, soil, water, fish and possibly human volunteers who have consumed wild game.

What do preliminary tests indicate?

Although no specific guidelines exist for wild game, the test results indicated that PCB levels for most of the samples were within the guidelines developed by Health Canada for similar domestic animals (beef).

What about cattle or other livestock in the area? Will they be affected?

Preliminary information indicates that there are no cattle or livestock in the potentially affected area. Animals in other areas are not at risk.

Can I eat fish caught from the area?

Fish should be treated the same as wild game and should not be consumed until the health risk assessment results are released.

Why wasn't the advisory issued sooner?

The advisory was issued by Alberta Health as soon as evidence was presented by Alberta Environmental Protection to suggest wildlife in the surrounding area may have been exposed to contaminants.

Alberta
HEALTH

Edmonton, December 23, 1996

HEALTH ASSESSMENT UPDATE
SWAN HILLS AREA

BACKGROUND

- On December 13, 1996 Alberta Health issued a public health notice advising against eating wild game and fish taken within a 30 kilometre radius of the Swan Hills Treatment Centre.
- The advisory was based on preliminary test results received from Alberta Environmental Protection as a result of an October 16, 1996 air emissions release containing Poly Chlorinated Biphenyls (PCBs), dioxins and furans at the Treatment Centre.
- The advisory was a precautionary measure as there was **no evidence of immediate risk to human health**.
- Some area residents continue to have concerns about the potential health risk involved.

DETAILS OF THE HEALTH ADVISORY

- Preliminary results of testing on animal samples indicate **no immediate threat to human health.**
- As a precautionary measure to minimize any potential health risks, individuals should avoid eating any wild game or fish taken from a 30 kilometre radius of the Swan Hills Treatment Centre. This radius has a large built in safety factor to take into account the movement of wild game.
- At this time there is no need to throw away the meat of the game taken within the 30 kilometre radius. This meat should be stored in the freezer with clearly marked labels until further testing is completed.
- **No immediate health risk has been identified at this time**. Therefore there is no need to be concerned if some of the meat has already been eaten. Just do not eat any more of the meat until further testing has been completed. Health effects are unlikely to occur as a result of eating of contaminated meat unless consumption is on a regular basis over a number of years.
- At this time there is no evidence that the meat from the 30 kilometre radius is significantly contaminated. **However, to be absolutely safe, eating the meat should be avoided until further testing is complete.**
- Alberta Health, in cooperation with the local Regional Health Authorities, Health Canada and Alberta Environmental Protection, is moving quickly to conduct a full health assessment in the area and will provide further advice by about the end of January, 1997.

DETAILS OF THE HEALTH ASSESSMENT

- The health assessment being done will determine the amount of contaminants to which people and wildlife were exposed and what, if any, longer term health precautions may need to be taken, especially related to eating wild game and fish from the area.
- The health assessment will include further testing of meat samples already taken from the area, as well as testing of new samples to be taken in the next few weeks.
- The health assessment will also include the testing of a random sample of people from the area, to assess human exposure to the contaminants. It will include both people who regularly eat wild game and those that do not. This will take place in early January, 1997.
- Alberta Health will be assisted in the health assessment by an expert Science Advisory Committee of independent scientists who will bring expertise on the possible health effects of the contaminants involved; oversee the overall assessment; and provide an independent review of the results.
- The first results of the full health assessment will be available by late January, 1997 or early February. At that time Alberta Health will issue further advice on eating wild game from the area.

FOR MORE INFORMATION

- Alberta Health, in cooperation with the local Regional Health Authorities, will release information on the results of the health assessment once the additional testing is completed in January 1997.
- Individuals with further questions regarding eating wild game taken in the general Swan Hills area should contact their local Regional Health Authority: **Aspen at (403)349-8705,** and **Keeweetinok Lakes at (403) 523-4434**
- Individuals with questions or concerns about specific personal health concerns should consult their physician.
- Individuals with questions about Alberta Health's overall health assessment should contact the **Alberta Health Communications Branch at (403) 427-7164.**

Appendix B

Public News Release (May 1997)

Alberta
HEALTH

News Release

Edmonton, May 15, 1997

Wild Game Public Health Advisory Downgraded

The wild game public health advisory for the Swan Hills area originally issued on December 13, 1996, has been revised by Alberta's Provincial Health Officer, Dr. John Waters, based on the results of more extensive wild game testing.

While recent test results confirm that eating wild game from the Swan Hills area poses no immediate threat to human health, it is recommended that individuals limit the amount of wild game eaten. The original public health advisory recommended that wild game taken from within a 30 km radius of the Swan Hills Treatment Centre not be eaten.

"Again, we have chosen to err on the side of caution with this matter. As the Provincial Health Officer, it is my responsibility to recommend the precautions necessary to ensure public health is protected", stated Waters.

The original advisory was based on two animal tests received from Alberta Environmental Protection and came following an air emissions release containing polychlorinated biphenyls (PCBs) dioxins and furans at the Swan Hills Treatment Centre on October 16, 1996.

Recent wild game meat samples taken from near the Swan Hills Treatment Centre were also found to have elevated levels of PCBs, dioxins and furans. "None of the levels detected in the wild meat samples are high enough to cause any immediate health problems, nor to cause undue concern for people who may have consumed the meat before the advisory was issued", said Waters.

"However, because we have detected elevated levels of contaminants and because these toxic chemicals accumulate with time, over the long-term it is prudent to limit consumption of game taken from within a 30 km radius of the Swan Hills Treatment Centre", said Waters. As a result, Waters is adjusting the advisory and is recommending the following precautionary measures:

- limit consumption of wild game taken from within a 30 km radius of Swan Hills Treatment Centre to 13 ounces per month (370 grams)

- avoid eating organ meat (liver, kidney) or using fat from game harvested within a 30 km radius of the treatment centre
- pregnant or breast feeding women should avoid eating wild game taken from within a 30 km radius of the treatment centre
- young children should avoid eating meat taken from within a 30 km radius of the treatment centre
- continue to avoid eating fish from within a 30 km radius of the treatment centre until fish sample testing is complete

The advisory applies to animals taken last fall, as well as to those that will be taken in the coming year. The advisory is in effect until further notice. As the health assessment continues and ongoing monitoring is conducted, the public health advisory will be updated as required.

The primary risk of contamination comes from eating animals that contain elevated levels of these contaminants. Contaminants in air and water are not of direct concern to human health.

Since December 1996, Alberta Health has been conducting a human health assessment. The assessment includes testing wild meat samples, human blood samples and fish samples from the Swan Hills area. Today's revised public health notice is based on the results of the wild meat samples. Blood test and fish test results are expected within the next two months.

Individuals who have questions may contact the Medical Officer of Health, Keeweetinok Lakes Regional Health Authority at 458-7715, or the Medical Officer of Health, Aspen Regional Health Authority at 962-9687.

Media inquiries should be directed to:

Dr. John Waters
Provincial Health Officer
Alberta Health
(403) 427-5263

Garth Norris
Director, Communications
Alberta Health
(403) 427-7164

Alberta
HEALTH

Backgrounder

Edmonton, May 15, 1997

Questions and Answers

1) Who assisted the Provincial Health Officer with the assessment and advisory?
Two committees were formed to help direct the assessment and assist the Provincial Health Officer with the advisory.

The Scientific Advisory Committee provided objective professional advice on scientific matters related to the human health assessment. Membership included scientists with collective expertise in the fields of medicine, human health effects, environmental epidemiology, wildlife biology, animal and human pathology, transport of environmental contaminants, and environmental health.

The Public Health Advisory Committee was established to assist the Provincial Health Officer in assessing potential public health risk. The team included representatives from Alberta Health, Keeweetinok Lakes Regional Health Authority, Aspen Regional Health Authority, Health Canada, and Alberta Environmental Protection.

2) How many Swan Hills and area residents eat wild game?
62% of the population in the area does not eat wild game. Approximately 2% of the area residents eat wild game daily, 11% eat wild game weekly, 13% eat it monthly and 11% of the population eats wild game once yearly.

3) What is the 13 ounce limit based on?
The 13 ounce limit is based on lifetime exposure to the most contaminated meat. Although not all animals in the Swan Hills area were found to be contaminated, utmost caution is being exercised to ensure public safety.

4) Why is the advisory being altered at all if only 13 ounces of the wild game can be eaten per month?
The initial advisory was a precautionary measure until further scientific data was available. We have now conducted thorough sampling and have revised the public health notice based on scientific data.

5) Why wasn't the updated health advisory issued after the results of the upcoming human blood sampling and fish samples were received?
Alberta Health made a commitment to release results and any revisions to the public health advisory as soon as results were available.

6) Why is it recommended that organ meat not be eaten?
Higher levels of PCBs, dioxins and furans tend to concentrate in greater quantities in organ and fat tissue. The highest levels of these chemicals in the Alberta study were found in liver samples.

7) How should the organs be disposed of?
No special precautions need to be taken to dispose of the organs.

8) Why shouldn't women who are pregnant or breast feeding eat this meat?
In the case of pregnant women, fetal development may be impaired by PCB, dioxin and furan contamination. The chemicals tend to accumulate in the brain of the fetus. Breast feeding women should avoid eating the meat as breast milk contains high levels of fat and these contaminants concentrate in fat.

9) When will the blood test and fish sample results be available?
The human blood and fish sample results are expected by the end of June. Blood samples from 100 Swan Hills area residents will be tested and compared with samples from other blood donors in the province.

10) Why can't young children consume wild game taken from the area?
For the sake of taking all precautions possible, the Provincial Health Officer is recommending that young children do not eat wild game taken from the Swan Hills area to avoid possible impairments to healthy development.

11) How many samples were taken?
Four fresh deer and 60 deer and moose freezer meat samples were taken from the Swan Hills area. The samples include muscle, liver, fat, kidney and heart tissue.

12) What is the average level of PCBs found in the deer and moose samples?
Fresh deer muscle: 22 parts per billion (all samples on whole weight basis)
Fresh liver: 74 parts per billion
Fresh deer fat: 253 parts per billion
Freezer meat muscle (dear and moose within 20 km of plant) : 18 parts per billion

The standard acceptable level of PCBs proposed by Health Canada is 200 parts per billion in beef adjusted for fat content. Standards do not exist for wild game muscle or organs.

13) What is the average level of toxic dioxins and furans found in the fresh deer and moose samples?
Fresh deer muscle: 1 parts per trillion (all samples on whole weight basis)
Fresh deer liver: 500 parts per trillion
Fresh deer fat: 45 parts per trillion
Freezer meat muscle (deer and moose within 20 km of plant): 10 parts per trillion

The standard acceptable level of dioxins and furans, proposed by Health Canada is 20 parts per trillion in fish. Standards do not exist for wild game muscle, organs or for mammals.

14) What is indicated by the freezer meat samples?
By studying the freezer meat samples we are able to confirm that levels of contamination decrease as you move further from the plant.

15) What health effects of PCBs, dioxins and furans?
There is no reason to expect negative health effects even if you have been consuming the wild game. Health effects are seen only if a high level of exposure occurs over a number of years. In the rare instance where health effects have been experienced in cases around the world, health effects have sometimes included chloracne (an acne-like skin condition), skin discolouration, headaches, swelling around the eyes, weakness, numbness, weight loss, abnormal liver functioning, reproductive difficulties, endocrine disorders, cognitive impairment and cancer.

16) Can people with meat taken from the Swan Hills area have it sent in for testing?
Freezer meat samples are no longer required for testing. Those who wish to have meat tested will have to pay a private laboratory to do so.

17) Can residents or people who have consumed large quantities of the meat participate in the blood sampling that is underway?
Participants in the current scientific blood sampling study have already been identified. No further blood testing is planned after the current sampling is complete. A physician, however, can order patient testing if the physician feels it is medically required.

18) Does the 30 km radius consider the migration of game?
A safety margin has been built into the 30 km radius to take into account normal migration patterns of deer. However, if you are still concerned, follow the consumption guidelines.

19) Were wild game samples from other parts of the province tested?
Twelve deer from across the province were tested. Overall, levels of contamination were higher for samples from the Swan Hills area than for samples from the rest of the province.

Appendix C

Public News Release (September 1997)

Alberta
HEALTH

Edmonton, September 4, 1997 News Release

Swan Hills Blood Test Results Not Elevated

Blood tests taken from a random sample of Swan Hills and area residents are comparable to levels of PCBs, dioxins and furans in the Edmonton and area control sample and lower than other parts of the world, announced Alberta's Provincial Health Officer, Dr. John Waters.

"We are pleased that the blood tests do not indicate elevated levels of contaminants," stated Waters. "Most people living in developed countries have some levels of PCBs, dioxins and furans in their blood. The levels found in the Swan Hills area residents are actually below levels reported in industrialized countries around the world. As well, the Swan Hills and area blood samples are consistent with the control sample."

"However," added Waters, "Albertans are cautioned to continue to limit the amount of wild game they eat from the area since continued consumption of contaminated meat may lead to elevated levels of toxins in the blood. In some cases, such as pregnant or breast feeding women and young children, eating wild game from a 30 km radius of the Swan Hills area should be avoided altogether." The public health advisory, issued May 1997, continues and is attached.

The blood sampling is a single component of the Swan Hills health assessment and was conducted as a result of an air emissions release at the Swan Hills Waste Treatment Centre on October 16, 1996. The blood tests determine the amount of contaminants (PCBs, dioxins and furans) to which people may have been exposed. Approximately 100 randomly selected individuals from the Swan Hills area were asked to provide blood samples as part of Alberta Health's human health assessment. Sixty-five samples were received.

Since December 1996, Alberta Health has been conducting a human health assessment. To date, the assessment has included testing wild meat samples and human blood sampling. The results of wild game testing, released in May 1997, indicated elevated levels of PCBs, dioxins and furans in game surrounding the treatment centre. While levels of contaminants were not found to be high enough to cause any immediate health concerns, a public health advisory was issued as PCBs, dioxins and furans may accumulate over time.

Albertans are reminded that the public health advisory includes the 1997 hunting season.

For more information, please contact:
Dr. John Waters
Provincial Health Officer
Communications
(403) 427-5263

Garth Norris
Alberta Health

(403) 427-7164

Alberta
HEALTH

Backgrounder

Edmonton, September 4, 1997

Wild Game Public Health Advisory

- limit eating wild game taken from within a 30 km radius of the Swan Hills Treatment Centre to 13 ounces (370 grams) per month;
- avoid eating organ meat (liver, kidney) or using fat from wild game harvested within a 30 km radius of the treatment centre;
- pregnant or breast feeding women should avoid eating wild game taken from within a 30 km radius of the treatment centre;
- young children should avoid eating wild game taken from within a 30 km radius of the treatment centre;
- continue to avoid eating fish from within a 30 km radius of the treatment centre until fish sample testing is complete.

The advisory is in effect until further notice.

Questions and Answers

1. **What do the blood test results indicate?**
The blood tests taken from a random sample of Swan Hills and area residents (those within a 100 km radius of the treatment centre) are comparable to the Edmonton and area control sample and are lower than the levels found in other countries and regions including such jurisdictions as Eastern Canada, the United States, Germany, Sweden and Norway.

2. **If the levels of these contaminants found in the blood samples are within normal ranges, does that mean the public health advisory is no longer in effect?**
The public health advisory, issued in May 1997, is still in effect. While blood samples are not elevated, eating significant amounts of wild game taken from the Swan Hills Treatment Centre area, over a long period of time, could potentially be harmful. Elevated levels of PCBs, dioxins and furans have been detected in game surrounding the treatment centre. Because these toxic chemicals accumulate with time, it is recommended that consumption of game taken from within a 30 km radius be limited.

3. **What were the average levels of contamination found in the blood samples?**
The average level of PCBs found in the samples taken from the Swan Hills area was 0.14 parts per billion while the control sample, or average, is 0.16 parts per billion. The average level of dioxins and furans (TEQ) found in the samples taken from the Swan Hills area was 18.30 parts per trillion while the control sample, or average (TEQ), is 14.36 parts per trillion.

   These levels can be compared to average ranges based on numerous studies conducted around the world which indicate that average levels of PCBs range from 3.0 to 6.8 parts per billion and average levels of dioxins and furans range from 12 to 54 parts per trillion.

4. **Will Alberta Health conduct any further testing?**
Alberta Health will complete the current study by analyzing fish samples from the Swan Hills area. The department will also review any results provided to them by Alberta Environmental Protection as part of the ongoing monitoring plan developed by Bovar at Environmental Protection's instructions. Alberta Health will provide recommendations from a human health perspective for inclusion in the long-term monitoring plan after the current health assessment is complete. The public health advisory will be reassessed on a yearly basis.

5. **How were people chosen to participate in the human blood sampling?**
500 people from the Swan Hills and surrounding area were randomly selected for participation in a telephone interview. Following the interview process, 100 individuals were asked to volunteer to participate in the blood sampling process. 65 Albertans participated.

6. **Do results indicate higher levels of contamination for those who regularly consume wild game than those that do not?**
No. There is no statistically significant difference between the blood samples from those who consume wild game and those that do not.

7. **Were aboriginals included in the human blood sampling?**

First Nations and Metis Albertans were included in the health assessment as part of the general population. The study was not targeted specifically at aboriginals. The number of aboriginals that participated in the study represents the proportion of the population that they make up. 72 aboriginals were telephoned in the survey and 10 aboriginals were asked to provide blood samples. Blood samples were received from 5 Metis and 1 First Nations participants.

There is no evidence to suggest that blood results of aboriginals differed from the results of all participants. Health Canada is conducting a separate study which will look at PCBs, dioxins and furans, eating patterns, and other health related factors in First Nations people.

Alberta Health Communications
(403) 427-7164

Appendix D

Public News Release (October 1997)

Alberta
HEALTH

News Release

Edmonton, October 30, 1997

Fish Consumption Limit Established for Lakes Near Swan Hills Waste Treatment Centre

Following fish testing, Albertans are advised that although they may resume eating fish from lakes in the Swan Hills Waste Treatment Centre area, they are cautioned to limit their consumption according to provincially recommended guidelines, announced Dr. John Waters, Provincial Health Officer.

Test results indicate that levels of PCBs, dioxins and furans in brook trout taken from Chrystina Lake, located close to the Swan Hills Waste Treatment Centre, are somewhat higher than levels in fish from Roche and Chip lakes which are located further from the plant.

As a result, Albertans may resume eating unlimited amounts of fish from Roche Lake and lakes and streams at least 20 kilometres from the Swan Hills Waste Treatment Centre, but are advised to limit the amount of fish they eat from lakes and streams located inside a 20 km radius of the Swan Hills Waste Treatment Centre. Beginning December 1996, Albertans were cautioned not to eat any fish taken from a 30 km radius of the Swan Hills Waste Treatment Centre until fish testing was completed.

"While no immediate health risk exists to those who consume fish from lakes within a 20 kilometre radius, test results indicate the fish have elevated levels of contaminants which may be harmful if regularly consumed over an extended period of time," said Waters.

"Again, we are being cautious by asking Albertans to follow this advisory. While the test results are not alarmingly high, they do indicate that limited consumption is prudent at this time," added Waters.

The Provincial Health Officer recommends the following precautions:

- X limit eating fish taken from within a 20 kilometre radius of the Swan Hills Waste Treatment Centre to 6 oz (170 grams) per week or less
- X avoid eating fish organs or eggs taken from lakes within the 20 kilometre radius
- X avoid eating fish from within the 20 kilometre radius if pregnant or breast feeding
- X young children should avoid eating fish taken from within the 20 km radius

Waters added, "If people choose to consume the recommended amount of 6 ounces of fish or less per week from the area, they can reduce the levels of contaminants in the fish even further by cooking it according to recommended guidelines".

The following fish preparation guidelines are recommended:

X remove the skin before cooking the fish
X trim the fat from the fish (belly flap, sides, back and under the skin)
X broil or bake the fish on a rack so the fats drips away
X do not use the drippings to prepare any other recipes

Three lakes were used for the fish sampling. Chrystina Lake is approximately 1.5 km from the Swan Hills Waste Treatment Plant, and Roche Lake is approximately 20 km from the plant. Chip Lake, located between Edmonton and Edson, was used as the control lake.

Currently mercury advisories are posted on some lakes within the 20 km radius, including Chrystina Lake. The mercury advisories recommend that fish from the posted lakes not be eaten. The 6 ounce consumption limit will apply to these lakes only in the event that the mercury advisories are lifted. The mercury advisories are currently under review.

The fish sampling was the final component of the Swan Hills health assessment initiated as a result of an air emissions release at the Swan Hills Waste Treatment Centre on October 16, 1996. To date, the assessment has included testing wild meat, human blood and fish.

A final report, reviewed by the Scientific Advisory Committee and the Public Health Advisory Committee, summarizes the results of the entire assessment. Blood test results from Swan Hills and area residents are comparable to levels of PCBs, dioxins and furans in Edmonton and lower than other parts of the world. However a public health advisory continues to be in effect limiting the consumption of wild game taken from the area as continued consumption may lead to increased blood contamination levels over time.

The final report also includes initial details of a long-term monitoring plan. The levels of contaminants in wild game and fish will continue to be monitored annually, human blood sampling will occur if warranted by the wild game and fish results, and the public health advisory will be updated as required.

Albertans are reminded that the wild game public health advisory remains in effect in addition to the fish advisory.

For more information, please contact:
Dr. John Waters
Provincial Health Officer
(403) 427-5263

Garth Norris
Alberta Health Communications
(403) 427-7164

Alberta
HEALTH

Backgrounder

Edmonton, October 30, 1997

Wild Game and Fish Public Health Advisory

Wild Game

X limit eating wild game taken from within a 30 km radius of Swan Hills Treatment Centre to 13 ounces per month (370 grams);

X avoid eating organ meat (liver, kidney) or using fat from wild game harvested within a 30 km radius of the treatment centre

X pregnant or breast feeding women should avoid eating wild game taken from within a 30 km radius of the treatment centre

X young children should avoid eating wild game taken from within a 30 km radius of the treatment centre

Fish

X limit eating fish taken from within a 20 kilometre radius of the Swan Hills Waste Treatment Centre to 6 oz (170 grams) per week or less

X avoid eating fish organs or eggs taken from lakes within the 20 kilometre radius

X avoid eating fish from lakes within the 20 kilometre radius if pregnant or breast feeding

X young children should avoid eating fish taken from within the 20 kilometre radius

Fish Preparation Instructions

X remove the skin before cooking the fish

X trim the fat from the fish (belly flap, sides, back and under the skin)

X broil or bake the fish on a rack so the fats drips away

X do not use the drippings to prepare any other recipes

The advisory applies to animals and fish taken in the fall of 1996, as well as to those taken in the current year.

Alberta Health
Communications
(403) 427-7164